Strategic design of a medical consumable

From product to circular service

Master thesis
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Master thesis

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Acknowledgements

Before you is the end result of my graduation project, which has consumed a big part of my life during the past months. Without a doubt, it has been one of the hardest projects I have ever done, but a rewarding ending of my time as a student. I could not have done it without the support of all my supervisors, friends and family and would like to thank them here.

First of all, I would like to thank Ruth and Brian, my chair and mentor. Both of you provided ongoing support even though I'm not always the most communicative person. Thanks for your practical advice, engagement and for bearing with me these final months.

Michael and Kevin, who have been a big support from Philips. Thank you for giving me the opportunity to graduate at Philips and showing me the ropes, the occasional grilling and your advice.
A special thanks to Raquel for providing much appreciated help and being incredibly quick with providing feedback.
The intern group in building HTC 33, who made my time at Philips a lot more fun and all shared the same struggles.

Finally, I would like to thank my family and friends for being there along the way. My parents for their unconditional support and believing in me throughout all my endeavours no matter what.

Thanks to Taco for the help and hearing me going on and on about the project.

Last but not least, Sara, for bearing with me all these months, your help and support mean a lot to me.

Mike

Executive Summary

The world of today is facing a large environmental challenge. We all need to reduce our impact to remain sustainable. Companies must look at a more circular approach of producing their goods. Without consumers engaging in circular behavior however, the circular economy will not reach its potential.

To examine the circular economy approach in a medical domain, a case study is done at Philips Design. Specifically, we look at the Healthdot, a medical sensor for at home, currently not envisioned to become circular, being developed by a venture team within the company.

The objective in the case is: How can we engage patients to send back the device after wearing it at home in order to enable a circular offer for the Healthdot?

To find opportunities that make a circular offer for the Healthdot the product and its ecosystem is analyzed. When a device with the current product design can be recovered, the PCBA can be reused. To increase circularity, it needs a redesign. A feasible redesign allows every component except for the adhesive part to be reused. Since the latter opportunity requires a redesign, it is a long-term opportunity.

Both scenarios require the Healthdot to be retrieved from the patients wearing it at home. The hospitals role is limited in this recovery. They are pressured to move the care they provide more outside of the hospital and extra handlings with a device means a less attractive value proposition towards them.

By interviewing ex-patients it became clear that the experience they have after surgery, is not pleasant in any way. Specific pain points throughout this recovery show potential to improve patient experience and motivate them to send back the device. Patients receive scattered and non-personal information, are physically and mentally burdened, are uncertain about their progress. Next to that, family and friends are heavily involved during this period.
Picking the device up at patients homes is an expensive undertaking and needs an additional pick-up service to be realized. The most promising opportunity is to have the device sent back by the patients.

According to Fogg (2009), three preconditions need to be present simultaneously for an action to happen. These elements are addressed in a first concept, which aimed to provide motivation through pleasure in the means of a package with insight in patients data. The concept increases their ability to perform the behavior by providing all the materials needed for send-back, together with clear instructions. The concept aimed to trigger them through several text messages.

After testing this with 6 other ex-patients and their partners at their dinner table, 4 main insights led to an improvement and final design.

- The hospital contacting patients created the feeling of reciprocation, this was perceived as the most motivating factor to send back the device.
- When patients are being monitored they have expectations for meaningful insight in the data. They except to hear something from the hospital related to their monitoring and recovery.
- Perceived as easiest to send back was taking it to a regular mailbox, when the materials such as a return envelope were provided and sending was free of charge. This allowed patients to be in control of when and where exactly to return the healthdot.

- Physically moving the device out of the house while sending back resembled closure of a recovery phase for patients.

These insights led to a final solution of an advent calendar, communication platform and a redesigned device. To reach this solution in 2022, the first step that can be made towards the end of 2020 is a concept that entails a messaging service and send-back materials for the patients.

One component of the final solution is an advent calendar that patients receive when they are discharged. It is to be placed at their homes, and includes several boxes to be opened during the recovery phase at home. The final box includes all material needed for sending back the Healthdot.

The calendar works together with a communication platform. Patients receive notification when they can open another box and QR-codes link to the platform. Healthdot functionalities are integrated in a larger communication platform in development by Philips. The platform enables communication between different care providers and the patient. It also can be accessed by a patients partner or other loved one, if permitted.

The Healthdot needs a redesign to increase value retention and go from a parts recovery strategy on the short-term, to refurbishment for the final solution. This redesign would enable reuse of all components except the adhesive part of the device.

The Healthdot becoming circular results in a triple win. Philips is able to save money, improve their value proposition towards hospitals and can add yet another proof point of sustainability to their repertoire. The patients will go through an improved recovery experience compared to the current experience. Thirdly, the environmental impact decreases through the reuse of components and less intensive use of the full manufacturing processes. This thesis led to the Healthdot venture team pursuing circularity already on the short-term, instead of a future possibility on the longer-term.

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Introduction

The introduction chapter consists out of two parts. Described first is how the environmental crisis leads to a case study in the context of the medical domain. Then the original offer of a medical consumable is introduced and explained as the starting point of the case study. The three main stakeholders for the execution of this thesis project within Philips are introduced and why this is an interesting case study for them.

The second part introduces the project objective and the main research question of this thesis. Finally, the approach taken to reach the objective is explained supported with a visual overview.

1 Introduction

1.1 Project Context & Royal Philips

1.1.1 Environmental concerns

The past decades have shown an immense increase in the use of resources. Current levels of resource consumption are 1.7 times the carrying capacity of the planet (Sengupta, 2017). Looking into what happens after the use of resources or because of use has become increasingly important. Waste, pollution and climate change are harming humans and the environment we live in. As the current linear "take-make-dispose" model becomes increasingly unfit and its limitations and risks become clearer, the need for shifting towards a new model is getting higher. If we want to be able to achieve the goal of the Paris Agreement (UN, 2015), limiting global warming to 1.5 degree above pre-industrial levels, we need to act. Tighter environmental standards and universal goals such as the Sustainable Development Goals (UN, 2019) stimulate companies to work towards a more sustainable future. This has put an increasing pressure on (industrial) businesses to lower their environmental impact.

When looking at one particular industry, the medical industry for this project, it becomes clear that the amount of waste differs per country. In the Netherlands, 1,7 kg of waste is created per hospital patient per day. Throughout other EU countries the amount of waste ranges from 1,2 kg (Latvia) to 4,4 kg (Spain), with other EU countries in between those (Norway 3,9 kg, UK 3,3 kg). In the US, this amount is much higher at 8,4 kg and in Mauritius it is as low as 0,44 kg (Minoglou et al., 2017). Additionally, home healthcare in the US generates an additional 50.000 tonnes of waste per year. As global healthcare is growing, due to emerging markets and ageing populations (Deloitte, 2018), we need to be concerned about this. Next to the healthcare sector growing, the UN estimated that healthcare waste puts over half the world's population at risk to illnesses it can cause. (Georgescu, 2011)

Currently most of the activities for the healthcare industry (as well as many other industries) follow the principles of a take-make-dispose linear economy. To move away from this linear economy, the concept of a circular economy was developed.

Royal Philips is a company that is under the pressure to lower their environmental impact. As a large multinational company, they have been adding to the rise of resource consumption for decades. Over the last years, their focus has shifted towards the healthcare industry. The healthcare industry is producing enormous amounts of waste, mainly due to hygiene regulations. The numbers mentioned ealier make it clear that adding to the waste in the health industry is not to be taken lightly. This creates pressure from governmental regulations for example on both hospitals, as well as Philips, to lower their environmental impact.

As a producer of medical equipment, Philips has the opportunity to influence the products that are used in hospitals. Each year Philips puts around 40,000 tons of hospital equipment and 200,000 tons of personal health appliances onto the market (Philips, 2018). With the ambitions Philips set for itself, it is now committed to move towards the circular economy.

Shifting from a linear business to a circular one however, is not a simple task. There are many different aspects to take into account. Philips can not move towards becoming a circular business on their own. It needs the help of their users. Even if a product is designed perfectly to be reused, if a user doesn't return it, it's potential goes to waste.

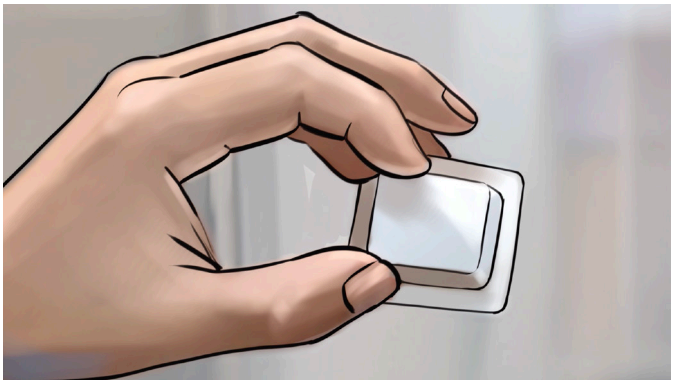


Figure 1: A sketch showing the size and looks of the Healthdot (image made by Philips)

1.1.2 Healthdot

To see how the circular economy can work in the medical domain when the end users are taken into account, a case study is done at Philips. The project will look into a medical monitoring device currently in development at Philips. This device is called the Healthdot.

The HealthDot is a small wearable product, similar to a band-aid, that enables remote monitoring of a patient after they have had surgery. Figure 1 shows the size of the device. The thicker middle part is the casing with electronics inside and the outer part is an adhesive.

The healthdot measures several vital signs of a patient and communicates the data captured with a monitoring dashboard that will be in the hospital. The product enables hospital staff to monitor patients when they are discharged and gone home. This provides hospital staff with insights that normally require patients to stay in the hospital.

It is applied to patients after surgery, who will then go home while wearing it. They will wear it for 14 days from the moment the device is applied to them. For some patients this will means they can go home earlier after surgery then currently is the case without the Healthdot.

The product is currently being developed by the Healthdot venture team, that is working on launching the device in 2020. It has moved from an internal research project towards piloting with hospitals and is now trying to move onto the market.

The original offer of the device makes it fit in the non-desirable take-make-dispose pattern. It is a transactional sales offer and Philips will sell the devices to hospitals. There it will be used by hospital staff and worn by a patient. Figure 2 shows a rough workflow of the original offer and what happens from step 6 onwards is still unclear. This is the starting point for this project.

Involved stakeholders

The project is executed at Philips Experience Design on the High Tech Campus in Eindhoven. The stakeholders involved in the project from Philips are as follows:

- HealthDot venture team: The team responsible for the development of the Healthdot offer. They are interested in the potential of going circular and improving their offer to the hospital.

- Group Sustainability: Currently developing a circular strategy for the product category medical consumables. The Healthdot is a real case to apply the circular framework for medical consumables, specifically exploring the adequate design strategies and a potential service model for this consumable.

- Circular design team: The circular design team is supporting circular innovation, interested in a case where circularity needs to be implemented in a venture and one that needs to include reverse logistics.

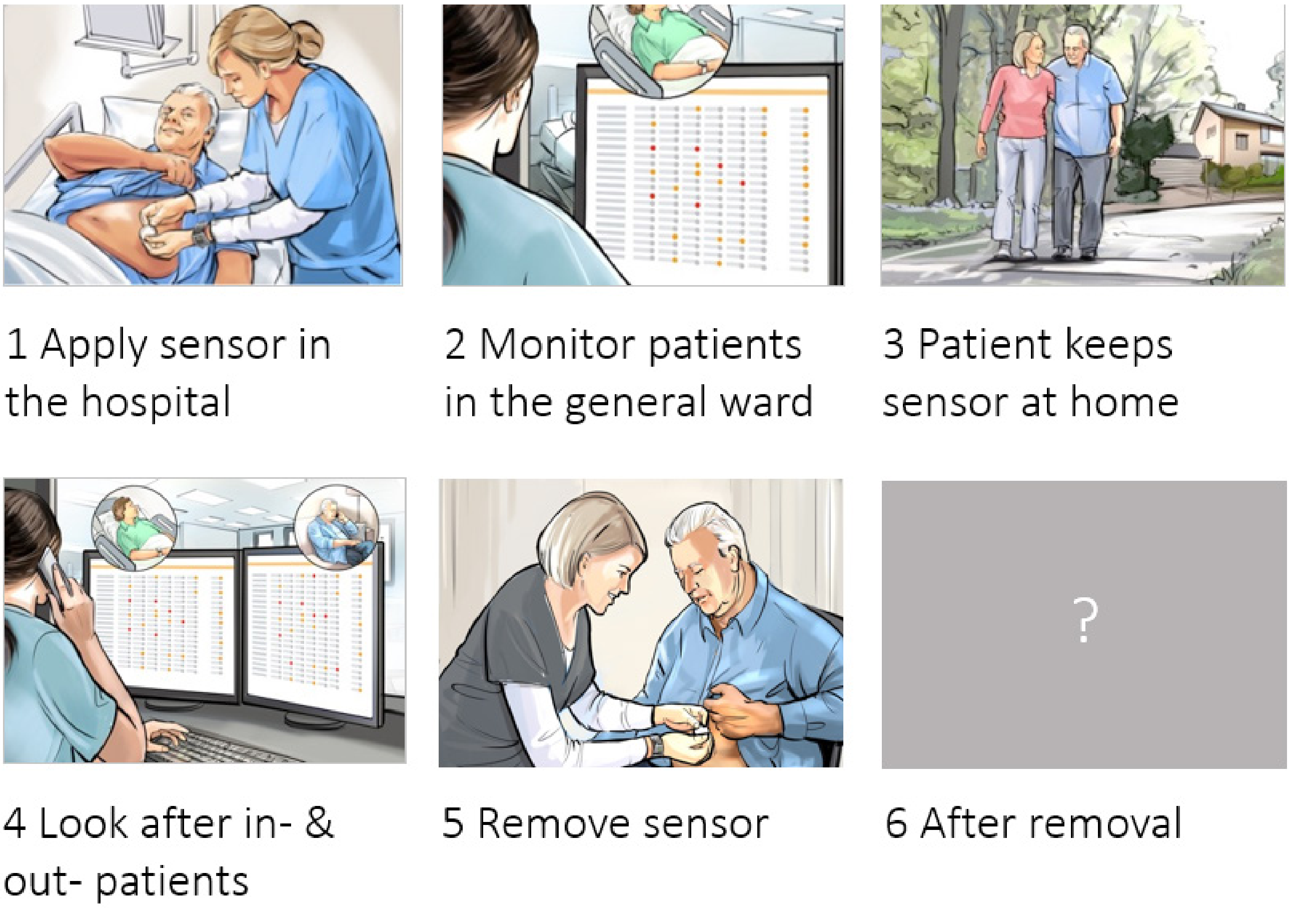


Figure 2: Step 6 shows the focus point of this project in the workflow of the original offer (images are made by Philips)

1.2 Project Objective & Approach

The core aim of this thesis is to examine what a strategy should entail to move towards a circular healthdot offer. As Philips is in a transition towards the circular economy, this project investigates different aspects of that transition. This means taking into account the product itself, the reverse logistics and the change in user behavior.

In parallel with this thesis, the healthdot venture team is also progressing with the development of their offer. As they aim to have the first batch being used by hospitals in 2020 the concept developed in this project should be able to increase the circularity of that batch. This means the original offer is used as a context and the focus is on feasible implementation for the first batch. The healthdot offer is a unique case in which every time a device is used, it goes home with the patient. Due to the nature of the device the proposition differs from the majority of medical devices, that stay in the hospital throughout their lifetime.

1.2.1 Project objective

Engaging patients to send back the Healthdot after wearing it at home in order to enable a circular offer.

Problem

Patients recovering from surgery have both physical and mental limitations while the desired behavior has no added value for them.

Assignment

Design a service concept that enables and motivates the patients to send back the device for circularity.

Research question

How to enable and motivate patients recovering from surgery at home to engage in circular decision making and send back the device?

Deliverable

A service concept for the Healthdot, enabling a circular offer for the Healthdot and improving the patient experience.

1.2.2 Project approach

Figure 3 on the next page shows the general approach taken within this project. The project objective consists out of two parts; Engaging the patient and the circular offer. Since the focus is on implementation with the original offer as starting point the possibilities for a circular offer with the original product design are examined first. From the project goal onwards a literature review is done, including academic and grey literature.

An in-depth analysis on the product, its context and patients lead to framing the problem and requirements in a design brief.

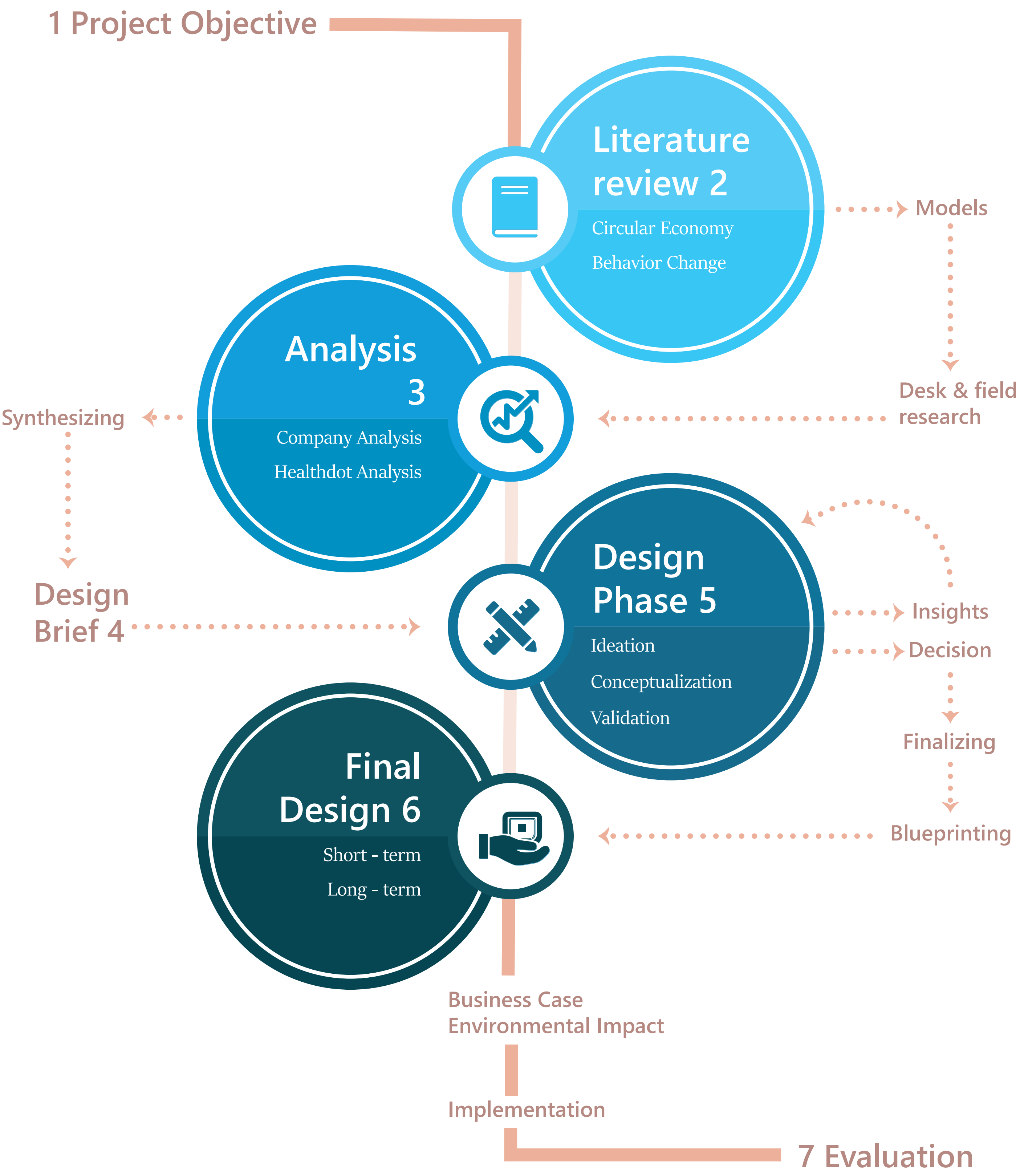
From the design brief the first ideation starts, followed by conceptualization. Feedback is gathered on the concept to evaluate, leading to a new iteration. After conceptualizing again it is evaluated similarly, this time leading to an experiment.

After the experiment, the design is iterated again and the final concept is developed. Through a blueprint the concept is detailed, and finalized into a final solution supported with a business case and implementation steps. This results in a triple win where both Philips, the patients and the environment benefits.

Abbreviations:

B2B = Business to Business
CE = Circular Economy
EMF = Ellen MacArthur Foundation
EoL = End of Life
OEM = Original Equipment Manufacturer
CAPEX = Capital Expenditures
LCA = Life Cycle Assessment
HAI = Hospital Acquired Infection

Figure 3: An overview of the general approach within this project.



Analysis:
Literature Review

The objective of this part of the thesis is to provide the necessary background knowledge on both the topics of circular economy and behavior change. It is divided in two main parts that cover these. The first part introduces the circular economy, how it works and its status in the medical domain. The second part on behavior change leads to elements of a behavior model, several techniques and elements of choice architecture. These elements and techniques will be used in both the analysis and design phase of the project.

This part of the analysis, the literature review, covers the literature used in this project. It was done by looking at both academic and grey literature. The relevant sources are obtained through both the company supervisors and TU Delft supervisors next to sources obtained by searching online.

2 Analysis: Literature Review

2.1 Circularity

2.1.1 Circular Economy

Originally, the circular economy concept comes from the field of industrial ecology. Since then it has become an increasingly popular model for moving away from a linear economy. There have been multiple researchers, as well as organizations, that have defined this concept. In this project a concept of circular economy (CE) will be used that comes from different material- and resource flow concepts (Ayres 1994; Braungart et al. 2008,2002; Stahel 1994, 2010; Lifset and Graedel 2002). It is described as follows:
"In a CE, the economic and environmental value of materials is preserved for as long as possible by keeping them in the economic system, either by lengthening the life of the products formed from them or by looping them back in the system to be reused." (den Hollander et al., 2017)

This is following the notion of waste no longer existing in a CE. Products and materials are, in a utopian view, reused and cycled indefinitely. Although there will always be unavoidable waste to a certain extent (Ciacci et al., 2015), the aim of a CE is to have a closed loop.

While Braungart et al. (2008) distinguish between "cradle-to-grave" and "cradle-to-cradle" clearly stating the difference between a linear pattern and a circular one, Stahel (1994,2010) refers to closed loop systems in which two different types of loops are described. These are then described as; 1) reuse, which in essence is the extension of the utilization period (e.g. through reuse, repair or remanufacturing) and 2) recycling, which means closing the loop between post-use waste and production. To be clear, closing the loop is not exclusively used to describe recycling. It can also be used to indicate closing the loop between end-of-use and recovery of a product to for example refurbish it.

The take-make-dispose pattern is one of the fundamental characteristics that has remained in our industrial economy despite all its changes. Nonetheless, major steps have been made towards resource efficiency and increasing awareness on the damaging effects of waste and pollution. Our industrial economy still consists mainly of resource consumption that follows a take-make-dispose pattern. Designing out material leakage, disposal or product obsolescence is something that requires more attention and requires the circular economy.

Next to the environmental reasons for the shift from linear to circular, there is also a great untapped economic potential. Net material cost saving is estimated between 340-380 billion USD and 520-630 billion USD (EMF, 2013). In figure 4 the conceptual representation of global resource flow and stocks made by Circle Economy shows "the circularity gap". Currently the world is only 9% circular (Circle Economy, 2019) and with the urgent necessity of a circular economy it is clear that this percentage needs to become much higher. In other words, this circularity gap needs to be closed.

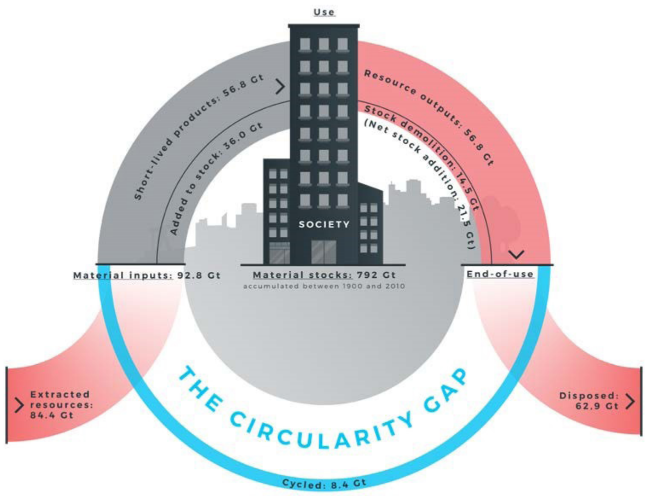


Figure 4: The Circularity gap (Circle Economy, 2019)

Butterfly Diagram
The Ellen MacArthur Foundation (EMF) that was founded in 2010 has been pushing to accelerate the transition towards a circular economy. The EMF created an overview to describe the circular economy: The Butterfly Diagram. This model shows different flows of resources within a circular economy. Figure 5 on the right page shows the Butterfly Diagram.

On the left side one can see the flow of renewables. On the right side is the flow of finite materials. The model shows different ways of 'looping' a product or its materials back into the system for reuse. Ultimately in a circular economy waste is eliminated by extending product life or performing an act of recovery allowing resources to flow back into the system.

2.1.2 Obsolescence
According to Burns (2010), a product is obsolete when a user does not consider it to be useful or significant anymore. Products becoming obsolete can have different reasons. Several forms of obsolescence can be found in literature, where the first 4 are discerned by Burns (2010): 1) Technological obsolescence where the product's technology is no longer relevant or outperformed by new technology 2) economic obsolescence where using the product is no longer profitable 3) regulatory obsolescence where a product is no longer legal and 4) aesthetic obsolescence where a product is out of fashion or damaged. Additionally there is 5) Functional obsolescence where the product no longer performs the function it's supposed to (Cooper 2010; Bartels et al. 2012; Tomczykowski 2001; Feldmann and Sandborn 2007).

According to den Hollander et al. (2017): "all obsolescence ultimately is a loss of perceived value (i.e., desire or affinity) of the product and/or system". Therefore, multiple kinds of obsolescence can lead to a product becoming obsolete. This should not lead to waste, however. To keep products in the economic system an act of 'recovery' (den Hollander et al., 2017) must be performed.

As can be seen in the butterfly diagram, there are different ways to return a product or its materials to the economic system and restore its perceived value. The different types of obsolescence as mentioned earlier lead to different methods of recovery needed. These different methods of recovery are briefly explained in the following paragraph as defined in literature before they are discussed in the context of the medical industry.

Repair (maintain/prolong in figure 5) aims to restore products from functional obsolescence, caused by specific failures. The product is reconfigured, or parts are replaced. Refurbishing or remanufacturing (Thierry et al., 1995) aims at products both obsolete or near obsolescence. Products need to be retrieved and crucial parts can be replaced. Den Hollander et al. (2017) argue for a distinction between remanufacturing and refurbishing. According to them, remanufacturing is different in dealing with intellectual property and the quality of a product after the process. As this is an important aspect in the highly competitive medical industry the distinction is also made in this project. If a product needs to be broken down to material level, in order to be recovered from obsolescence, the process is called recycling.

According to the 'intertia' principle of Stahel, these recovery methods can be ranked. That leads to the value hill model (Achterberg, Hinfelaar, & Bocken, 2016).

In essence this means that value can be maintained, and environmental impact minimized if a product is kept on top of the value hill as long as possible. Figure 6 shows this value hill model.

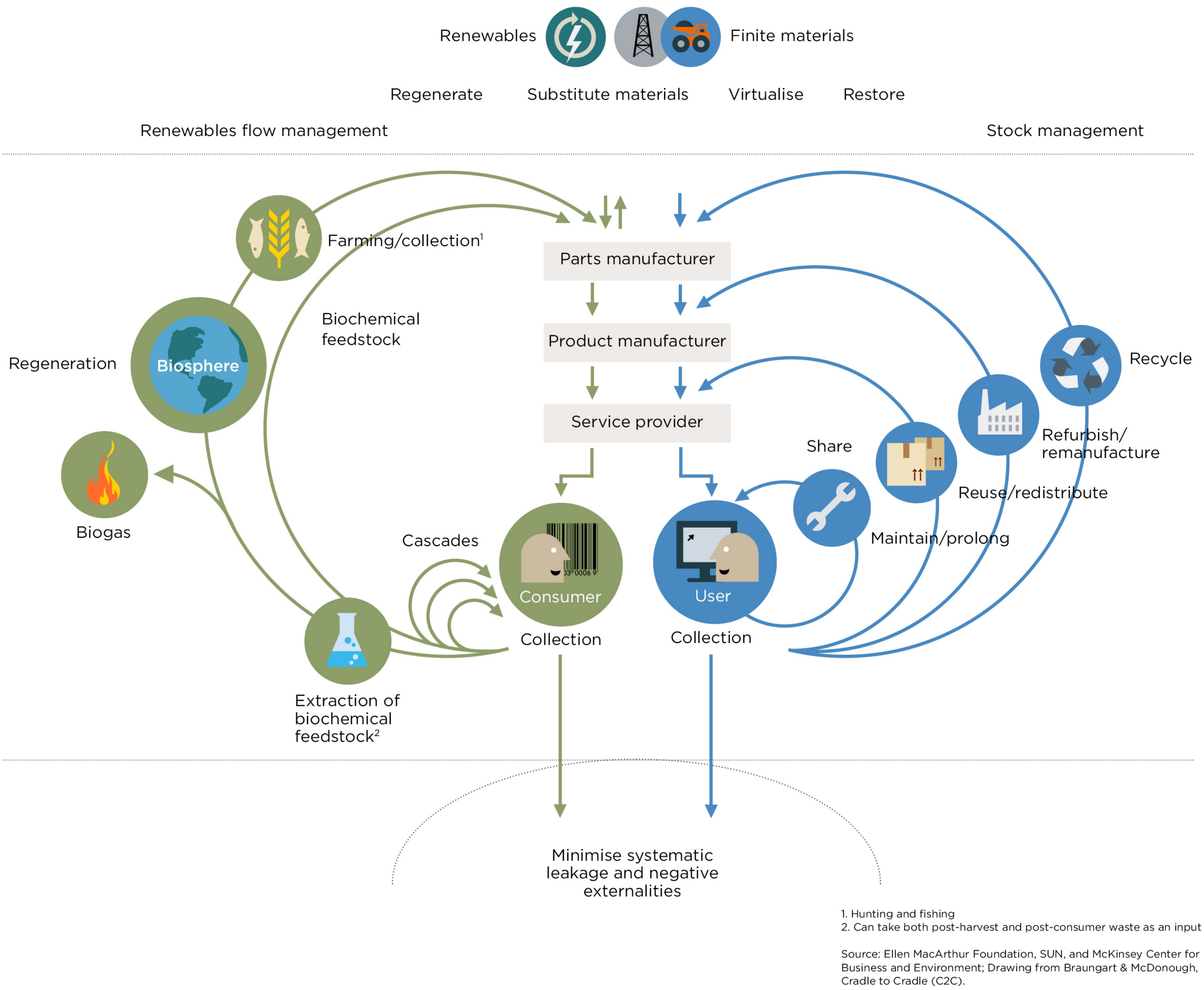


Figure 5: The Butterfly-diagram (EMF, 2013)

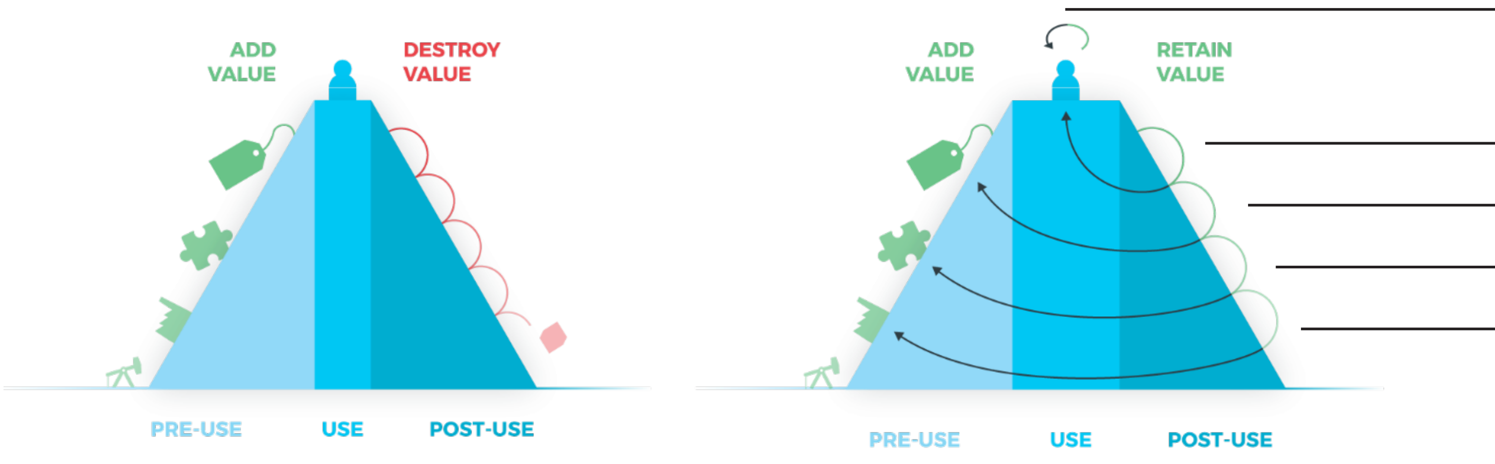


Figure 6: The value hill showing losing and retaining value. (Achterberg et al., 2016)

2.1.3 Medical domain

From understanding the need for a circular economy, it becomes clear that shifting towards a circular business from a linear one is a complex situation. The shift requires change in the product design, the business model, reverse logistics infrastructure and the behavior of the users. The healthcare industry is a highly regulated one and the use of single use disposable devices is a growing trend as they have helped reduce infections. In figure 6 is shown how the CE strategies in the medical domain fit on the value hill model.

As there is little research done into circular economy in a specific industry such as the healthcare industry (Kane et al., 2018), the existing knowledge about approaches in healthcare is discussed briefly. The explanation starts with the approach highest on the value hill and then moves down to other approaches.

Reprocessing

Sterilization is a phase in the reprocessing of devices that solely exists because of hygienic obsolescence. The type of sterilization or disinfection needed for a product is determined by its clinical function and hygiene criticality. Medical products can be categorized in terms of this criticality with the spaulding scale (Spaulding, 1968) . The decision to sterilize a product or not is influenced by the survival of the disinfection or sterilization process. Product requirements can therefore be set if it needs to survive a certain disinfection or sterilization process. Whether a device is labeled single-use or reusable is determined by the manufacturer. There are however cases where devices labeled single-use by the manufacturer, are being reprocessed by third party companies and sold again.

The bulk of devices undergoing this approach of recovery are medium-complex and have high- to medium-hygiene criticality.
Sterile devices are labelled sterile until their packaging is opened. These packages are often disposed together with other waste categorized as bio-waste. The effect of that packaging is discussed at "recycling" later in this chapter. Often the type of single-use devices, falling under Spaulding's non-critical category, are reused several times due to cost constraints in medical units. For example, ECG cables and Blood pressure cuffs.

Repair and maintenance

This process or activities are intended to recover a product from temporary functional obsolescence. The activity of repair and maintenance are frequently used CE strategies in large medical equipment with longer life times (i.e. 12-15 years).
The activity is usually performed by biomedical engineers trained in repairs and risks involved (Enderle, 2012). An increasingly common way to perform this act of recovery is through service contracts provided by the OEM. The OEM then handles repair and upgradability. Sometimes such contracts are the only possible way for this approach since the OEM is the only one allowed to work on the equipment due to competitiveness with IP rights. Such contracts then become part of the OEM's business model leading to dependencies on the revenue from those service contracts (Markets and Markets, 2016; Wang, 2016).

Refurbishment and Remanufacturing

Like described earlier, this is a process where products towards the end of their life are retrieved by the manufacturer and looped back into service. Before the products are put back into service, they are brought back to a certain level of quality. The difference between refurbishment and remanufacturing is that level of quality. Where remanufactured products need to be returned to the same or better quality as a new product. This approach mainly happens with expensive and complex machines such as MRIs. These often undergo multiple repairs during their lifetime but still have parts to be replaced or upgraded at the end of their overall finite lifetime.

Kane et al. (2018) found that this method of recovery is relatively widespread in the medical industry with roughly 2,5% of the total market consisting of refurbished and remanufactured products (9,37 billion of 381 billion). Emerging markets are increasingly purchasing refurbished products (Markets and Markets, 2015; Kalorama Information, 2016). International guidelines exist hence it seems refurbishing of medical devices is a mature and regulated practice in most of the world.

Usually devices brought back to the economic system through these processes are high-complexity and high-cost. Although there are some cases of small- to medium-complex devices these are usually part of hygienic recovery through reprocessing.

Commonly, the methods of refurbishing and remanufacturing focus on products that fall in the category technological obsolescence. The driving force for recovering this kind of equipment is reducing costs for end-users. This has proven to be a successful strategy due to the high value of products and relatively small costs of this method compared to the overall manufacturing costs.

Even though it is relatively widespread, and companies have set up refurbishing facilities, there are still some big challenges. One challenge is the balancing of cost-effectiveness between the manufacturing of new products and the refurbishment or remanufacturing of used products. The design requirements can conflict as a decision for manufacturing new products can lead to difficulties in refurbishing and vice versa. Next to that the supply chain in combination with market demand is challenging due to the lack of specified agreements leading to uncertainty in retrieving used products.

Recycling

Recycling is the process of breaking a product down to material level and recovering it to a useful form. 20-25% of medical waste is estimated to be recyclable plastic (Lee et al., 2002).

A major barrier for this approach with medical consumables is infectious waste. The strict regulations for healthcare providers regarding such waste from medical consumables makes it very difficult to obtain the recyclable plastics but also metals and other materials that can be recycled. The plastics and other materials suitable for recycling are lost as it is mixed with infectious waste. A term provided for this kind of obsolescence is “hygienic obsolescence”. A lot of potential for this approach is lost due to the “safety-first” culture in hospitals, where disposal as infectious waste is almost default. There is also evidence of this culture moving into hospital purchasing departments where reusable products are replaced with disposables even though the much environmentally friendlier reusables are similar in comfort and safety (Smithers Apex, 2014; Overcash, 2012).

2.1.4 Key Takeaways

- Due to waste produced in healthcare, circular practices are critical. However, it poses different challenges in terms of hygiene and focus of hospitals on providing care.

- Mostly high-value and high-complexity devices in the medical industry are being recovered, this makes that a small device like the healthdot might need high volumes and possibly stronger argumentation to persuade different parties.

- The main argument and reason for decision making regarding circularity is cost reduction. That means a part of the project needs to look at the implications the concept has for the business case, specifically on the effect of circularity on possible cost reduction.

- “hygienic obsolescence” is a category unique in medical domain that comes from behavior of hospital employees. This may lead to specific product requirements but also poses a challenge when these employees need to act. Next to that the way of cleaning a device for reuse differs per device which means the healthdot might need to be cleaned in a specific way.

- The manufacturer is the one who decides to label a device single-use or reusable. Even though a hospital is the customer, the manufacturer provides instructions for single-use or reusable. Philips would validate a product for a certain type of use, this also means they validate the amount of use cycles. This validation will also be necessary for the Healthdot when multiple use cycles are required.

2.2 Transition challenges

Transitioning from a linear way of working to a circular way of working causes different challenges as operations need to change. Since the Healthdot might need a redesign to become circular, different design approaches are looked up. Another possible challenge for the Healthdot are the reverse logistics, hence the project also looks into that aspect.

2.2.1 Design approaches for sustainability

As designers create products and services, they have an opportunity to influence how products and services are made. As a result, design has been partially responsible for most products following the linear take-make-dispose pattern. Closing the circular gap is therefore also something designers can have an enormous influence in. Hence there lies a huge responsibility for design in stimulating or catalyzing innovation towards a circular economy.

As the circular economy is regenerative and restorative by intention, and entails different ways of recovery, it follows that a crucial aspect of implementing a circular or closed loop approach is the design of circular products. In the previous part of the literature review, multiple "acts of recovery" and obsolescence types are described. To enable these acts and deal with obsolescence, they need to be designed for which means there are different design approaches possible to move towards circularity. Moreno et al. (2016) provided a comprehensive overview of approaches. The full overview can be found in appendix A.

As their overview provides guidance from the broad perspective of designing for sustainability, many options are not applicable for the scope of this project. Next to the relevant archetypes defined by them other also provide relevant definitions such as Bocken et al. (2015) and den Hollander et al. (2017). When the device needs a redesign to increase sustainability there are multiple approaches suitable. The approaches were investigated with the focus of implementation in this project in mind. That means the relevant design approaches either aim to slow loops (designing for longer use, extended use or recovery) or to close loops (designing for technological- and biological cycle or dis- and reassembly). After the possibilities for the Healthdot become clear, that also shows which approach might be the most relevant. Next to that the medical consumables strategy discussed in chapter 2.3.3 might specify these approaches aligned with the specific product portfolio already. In that chapter will thus be discussed if and how these approaches are used.

2.2.2 Reverse Logistics

Earlier the term "recovery" was used regarding the recovery of value of products and returning them to the economic system from obsolescence. Recovering product from obsolescence requires that products need to actually be recovered and returned through a logistics system. When comparing a linear economy with a circular economy, the final stage in the linear one is "use" and then disposal. In a circular economy, there is at this point an extension that closes the loop. Logistics are therefore a major enabler when it comes to scaling up circular economy and overcoming challenges within the value chain. This so called closed-loop supply chain considers the entire flow of material both in forward logistics as reverse logistics (Souza, 2013).

These reverse logistics cause quite a struggle for circular initiatives. That is mainly due to the complexity of managing the value chain from start to finish. Most logistics infrastructure is optimalized for forward logistics and adapting activities of all

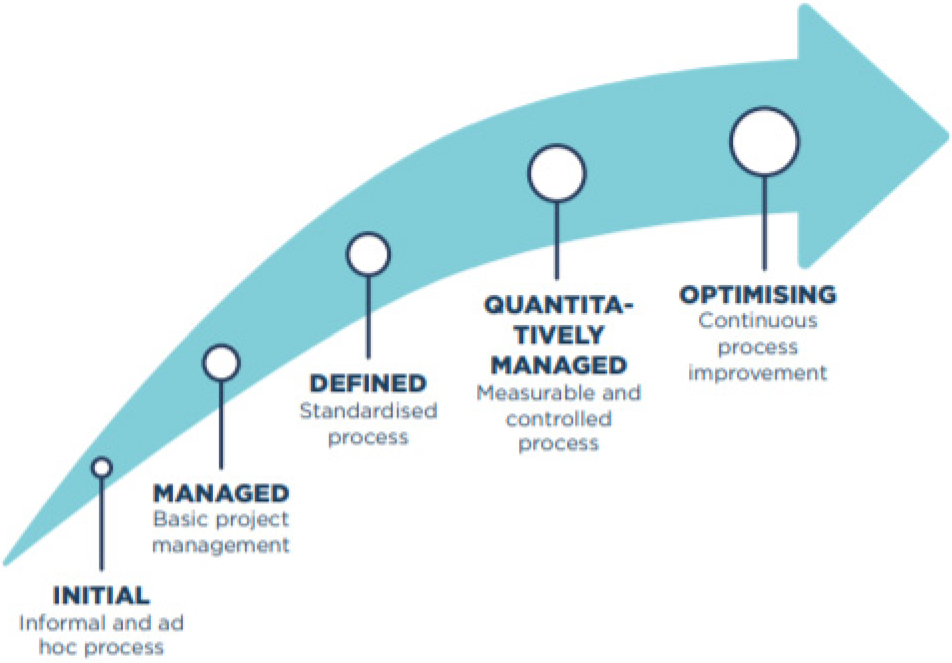


Figure 7: Different levels of maturity in reverse logistics (CE100, 2016)

parties involved throughout the value chain is a large operation.

Reverse logistics are key in getting value out of end-of-life goods and facilitating reuse models. Research on this topic is mainly concerned with in-depth supply chain models but lacks on linking product or service design with reverse logistics. However, the Ellen MacArthur Foundation created the 'reverse logistics maturity model' (CE100, 2016). This model provides different archetypes and practical guidance on how to improve one's reverse logistics operation.

According to this model a key success factor for products with low comparably residual value at the end of a product lifecycle is to realize an economy of scale. Incentivizing consumers or establishing collaboration programs might have a positive impact on return volumes.

Takeback systems can be categorized according to their "maturity" (CE100, 2016). The model distinguishes five different levels (figure 7). If a takeback system is being set-up it is in the initial level. It then has a standalone reverse logistics operation with goals limited to cost minimization, that is managed reactively and items are collected with no record of lead time, return rate and volume. The most mature stage will mean it is a cross-functional process throughout different business units. It is quantitively managed, optimizing the network and flow of products. It is continuously improved and can handle change in product mix, volume, equipment, sourcing and planning.

It is likely that the Healthdot will start at the initial level with the first possible retrieving activities. Once it becomes clear in the project that it needs to be retrieved the model can serve as guidance to recommend future steps for the Healthdot team.

2.2.3 Key Takeaways

- Existing design strategies for circularity that are applicable might be limited for healthcare and the specific Healthdot context due to regulations in place, therefore important to see what already exists within Philips.

- Product design requirements depend on type of recovery, meaning that if the design will be refurbished or only returned for parts harvesting it could lead to different designs. This means the Healthdot's design might need to change depending on the opportunities for recovery.

- Reverse logistics implementation goes step-by-step and cannot be set-up isolated from the rest of the company, this would mean even though the focus is on how to retrieve a specific product a company needs to approach it systematically.

- Product value is a factor in determining recovery strategy, as lower value products might need economies of scale to work. This adds to the previous insight on the importance of the financial aspect for the potential recovery.

2.3 Behavior Change

This chapter aims to introduce basic aspects of behavior change, specifically models that can be used practically in designing products and services. Explained is what models and techniques are used later in the project and what is the foundation of these.

In literature several models exist that focus on what happens in people's minds when deciding to act or not. For example the theory of planned behavior by Ajzen (1991). His model focuses on how someone's attitude towards a behavior, their subjective norms and perceived behavioral control influence the intention to perform a particular behavior.

Prochaska and Velicer's Transtheoretical model (Prochaska & Velicer, 1997) focuses on the different stages a person goes through. This starts with contemplating an action and moves to changing actual behavior and maintaining that behavior. These models, however, are not in the format of practical handholds that this project needs to design for behavior change.

2.3.1 Preconditions

Behavior itself is something that cannot be designed as Selvefors et al. (2016) mention. Designing for behavior can be done, by influencing people's preconditions for acting.

According to Fogg (2009), behavior change requires three preconditions. The three all need to be present at the same time for an action to happen. These preconditions in his behavior model are as follows: motivation, ability, and trigger. The model in figure 8 shows how these three relate to each other and indicates that increasing the motivation or making the action easier doesn't necessarily provide so much

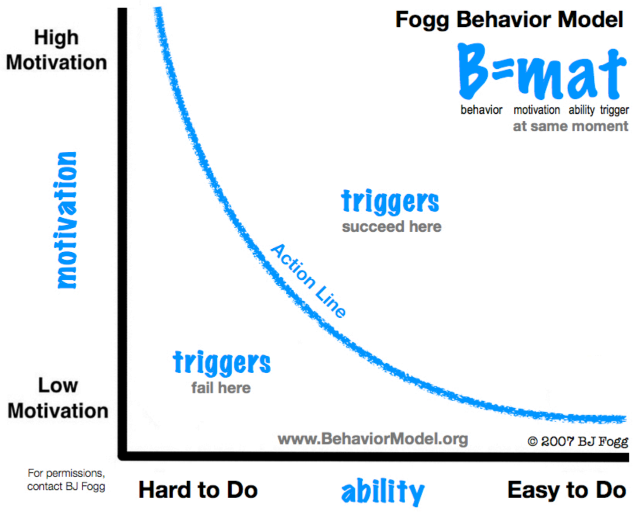


Figure 8: Fogg's Behavior model (Fogg, 2009)

improvement in behavior change.
Motivation consist out of three factors; pleasure, hope or social acceptance. The other sides of these are pain, fear or social rejection. Ability consists out of six factors: time, money, physical effort, brain cycles (mental effort), social deviance and non-routine (non-everyday activities). Triggers are generally ways of pushing people towards a behavior and stimulate one of the above factors. Three triggers are described by Fogg: A spark, increasing a person's motivation; a facilitator increasing a person's ability; a signal that usually only works when motivation and ability are already present.

Wendel (2014) builds on Fogg's behavior model. Since Wendel focuses on providing practical help, this project looks into his book more extensively.
He explains five preconditions and shows how they can be set-up for action. These five are as follows:
1) A cue to start thinking about an action 2) the reaction to that cue 3) evaluating the action 4) checking if one has the ability and 5) determining if

the timing is right. These can be put in the Create Action Funnel (figure 9). At each step, the user that needs to perform the action can be lost and won't act. Figure 9 shows this funnel and each step in which the user can be lost, resulting in inaction.

Three strategies are presented in the book to guide a user through this action funnel. The first strategy is "Cheat", where the aim is to take away as much work for the user as possible. An example of this strategy is creating a default where a certain option or choice that a user needs to perform is "yes" by default and the user can opt out. The second strategy is "Make or change habits" which like its name suggests is about creating habits. This strategy is particularly useful when user need to perform an action multiple times. For this project it is not a suitable strategy since the users only need to perform an action once.

The third strategy is "Support conscious action". This approach focuses on helping the user think about the action and guiding him or her to take the necessary steps and consciously decide to perform the action.

Since the objective of this project requires an action that cannot be fully eliminated for the user, the cheat strategy might only be partially useful. (this will be elaborated later in the thesis as eliminating the action fully is not perceived as easier by the users). The main strategy that is applicable for the Healthdot case is to support conscious action. According to Wendel (2014) this is the most difficult approach of the three. Thus , some additional approaches are looked at to help with this strategy.

2.3.2 Nudging and patterns

In this project both nudging and design patterns are used to support the conscious action. A nudge can be defined as follows: "Any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives." (Thaler & Sunstein, 2008)

Figure 9: The Create Action Funnel by Wendel (2014)

The preconditions mentioned before are also part of the choice architecture. Thaler and Sunstein (2008) explain six principles of good choice architecture that can be used to design for behavior change. These are the following ones: Incentives, Understand mappings, Defaults, Give feedback, Expect error, Structure complex choices.

Incentives in this case means focusing on providing the right incentives to the right people and looking at different ways of providing an incentive (eg. Not only a financial incentive). Understanding mappings can be used to make something more understandable for users. With mappings is meant the relation between a choice and the outcome of that choice. Defaults are similar to the "cheat" strategy mentioned earlier. Giving feedback means telling the user when they are doing it right or wrong. Expecting error means taking into account the errors people can make and using that to steer them towards the desired behavior. Structuring complex choices is helping users to simplify a choice and possibly steer them by doing this.

Lockton (2010) provides multiple techniques to design nudges. These techniques are put in a comprehensive toolkit. Several of these techniques are categorized and for this project the relevant ones are taken out of the full toolkit. In chapter 5 can be read more on how they are used during ideation. The toolkit includes many patterns that originate in different disciplines. Some of these are not applicable for the case in this project and are left-out.

2.3.3 Key takeaways

- Fogg's model indicates the three preconditions needed at the same time, for an action to happen. Wendel's model enables a decomposition of the behavior flow more detailed. This is useful to analyze the current and target behavior for the patients.

- The analysis of this project will be synthesized in the chapter 3 with Fogg's model and the Create-Action funnel. All preconditions will be specified with the context and users of the Healthdot case.

- "Support conscious action" is the behavior change strategy applicable for the Healthdot case as user only need to perform an action once, and the action can not be fully eliminated for them.

- Nudging and Lockton's toolkit are used as support since the "support conscious action" is the most difficult out of three strategies. Nudging and Lockton are therefore useful for several techniques to include in design phase, both as handholds and inspiration.

Analysis: Philips & Healthdot

The second part of the analysis focuses on Philips and afterwards goes into depth on the Healthdot offer. General activities within Philips are described such as the sustainability program and how the company defines its circularity ambitions including revenue streams. The circular activities related to the medical consumables product portfolio is then described and result in several design criteria applicable for the Healthdot.

Within the Healthdot offer the entire ecosystem is first discussed to provide an overview of relevant actors and all stakeholders. Flow models then show how the components flow into an assembled device and what the opportunities are to enable a "parts recovery" strategy and a "refurbish" strategy. For retrieval of the device, hospital staff is interviewed and this shows that their role is only limited. After interviewing ex-patients it becomes clear that they show the most potential for retrieval of the Healthdot.

3 Analysis:
Royal Philips & Healthdot

3.1 Royal Philips

The objective of the company analysis is to gather existing knowledge within Philips that can be used for the case of the Healthdot. This knowledge is useful to align with other initiatives within the company. The company analysis is divided in two parts of which the first one provides more general information on sustainability initiatives in the company, while the second one provides the current state of the circular strategy for medical consumables.

The company analysis is done through both desk and field research. Desk research includes online available material on Philips next to internal documents provided by company supervisors and Philips employees. Field research is done through conversational interviews with 8 Philips employees. These interviews also contribute to chapter 3.2.1 and 3.2.2 and will be explained more detailed in those chapters.

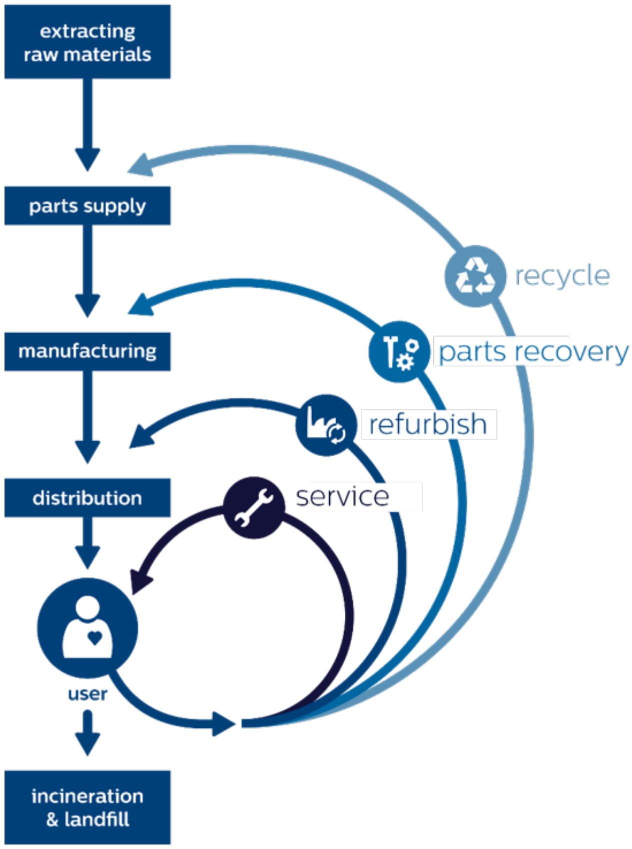


Figure 10: Partial butterfly diagram used by Philips

3.1.1 Sustainability Program

In 2016, Philips launched a five-year long sustainability program called "Healthy people, sustainable planet"(Philips, 2016). The company set an ambitious target in 2012 to improve the lives of three billion people a year by 2030. They aim to do this by making the world healthier and more sustainable through innovation. They are on schedule to reach this, with 2,2 billion lives in 2018. Key to getting to this target is the circular economy.
As a manufacturer of many products Philips has the opportunity to play a role in the global transition away from a linear economy and towards a circular one. They have set goals to innovate towards becoming more sustainable. By 2020 they want to generate 15% of sales from 'circular' products and services, increase Green Revenues to 70% of sales and recycle 90% of operational waste and send zero waste to landfill (Philips, 2016)
Next to that they aim to close the loop on all large medical systems equipment that become available to them and extend circular practices to all medical equipment including medical consumables by 2025.

Each year Philips puts around 40,000 tons of hospital equipment and 200,000 tons of personal health appliances onto the market (Philips, 2019). They strive to become carbon-neutral in their operations, using 100% renewable electricity.

Philips has specified acts of recovery with their own terminology. Figure 10 shows this in a partial butterfly diagram. These terms will be used from now on. This will make it easier to specify how the a circular healthdot contributes to the company's transition.

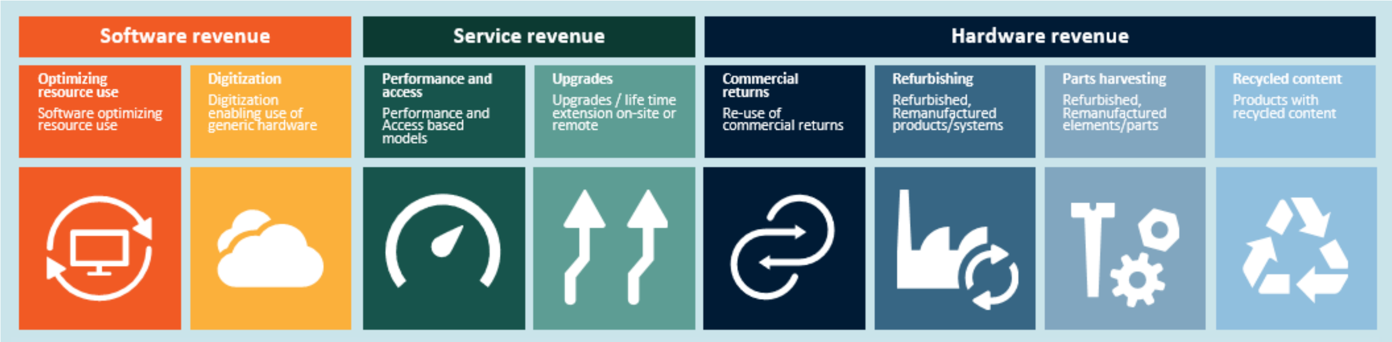


Figure 11: 8 circular revenue categories specified by Philips

Within Philips is defined what activities contribute to the circular revenues. Recently they have developed circular design criteria and established a connection on how this criteria can contribute to the circular revenue categories. These criteria are called circular readiness categories. These provide some guidance, although due to the uniqueness of the healthdot case, they are still too generic. In chapter 2.3.2 will be elaborated on a work in progress of specifying these criteria for the specific product portfolio of medical consumables. An overview of these readiness criteria can be found in confidential appendix A.

3.1.2 Medical consumables

Part of Philips' ambition to go circular is closing the loop on medical consumables. Medical consumables are products that complement the use of the large medical equipment. Philips offers single- and multi-patient use products. However, hospital practices in response to HAI, may lead to disposal of reusables more often than needed. Currently this category is not contributing to the circular revenue of Philips. By weight and use rate this category has a higher environmental impact than other CAPEX solutions, therefore an area that has a lot to gain by going circular. The goal is to have medical consumables contribute to circular revenues of Philips by 2025.

For this range of products a circular strategy is in development. Multiple initiatives regarding circularity within this product portfolio exist such as with ECG cables. The healthdot however, is particularly relevant due to its challenging use cycle where it moves out of the hospital every time where most devices remain in the hospital. Currently the vision for the medical consumables is: "A future, where Philips sells multi use-cycles consumables as a service" (Rebelo de Mira, 2019). Aligning with this would indicate aiming for multiple use cycles with the healthdot as well. To reach that, the focus will be on product design, business model innovation and reverse logistics.

From the 8 circular revenue categories shown above in figure 11, only a few would be applicable for the Healthdot. With the circular strategy for medical consumables still in development, there are only preliminary circular design criteria connected to the revenue categories. These are as follows:

- Easy to clean, sterilize and restore aesthetic state
- Easy to assess and track performance (detects material degradation, use cycles)
- Easy to disassemble, repair and re-assemble
- Modular design for forward and backward compatibility
- Standard, durable element selection

These criteria are relevant for "parts recovery", "access & performance" and "refurbishing". These criteria can serve as the basis for any criteria recommended for a redesign of the Healthdot.

In determining the circular strategy for the medical consumables, requirements specifying how products will be recognized to add to circular revenue will also emerge. These are usually quite detailed requirements that also serve as guidelines for product design. For other product categories these requirements mean that a product needs to retain more value than happens with recycling to add to circular revenue. Therefore, the assumption is made that for medical consumables this won't be any different. For the healthdot, this means that the original offer needs to change in a way that is at least more circular than recycling in order to add to circular revenues.

3.1.3 Key takeaways

- The goals is to have the product portfolio of medical consumables add to circular revenue categories as defined within Philips by 2025. Part of this goal is the Healthdot becoming circular.

- Circular strategy for medical consumables is in development. Current vision for this product portfolio is: “A future, where Philips sells multi use-cycles consumables as a service”. This indicated that the Healthdot needs to aim for being able to go through multiple use-cycles.

- Circular design criteria is developed in the company and linked to the circular revenue categories. With the circular strategy for the medical consumables in develoment, the criteria is being adapted to the portfolio. Three revenue categories might be relevant for the Healthdot which leads to 5 preliminary criteria used as a basis for possible redesign guidelines.

3.2 Healthdot

Finding the opportunities specific to the case of Heathdot is done by an in depth analysis of the Healthdot. The goals of this chapter is to provide an overview of the ecosystem in which the device operates and to identify opportunities for circularity on both product- and user level. Firstly, the ecosystem of the Healthdot is explained, followed by a flow model analysis. This shows the opportunities for circularity and will be the starting point for explaining the hospitals role and the patients role in retrieving the Healthdot.

This part of the analysis uses both desk and field research. The desk research includes both academic literature and internal documents provided by the company supervisors and other Philips employees. The field research uses the conversational interviews mentioned in chapter 3.1 as well. Next to that the field research uses semi-structured interviews with both hospital staff and ex-patients. Stakeholder mapping is done with a template and consulting several Philips employees. The insights of interviews with ex-patients are put in a customer journey map. Finally, personas are made to use later in the design phase.

3.2.1 Ecosystem

To create an understanding of the ecosystem of which the HealthDot will become a part of, a stakeholder analysis is done resulting in an ecosystem map. This started out by using insights and knowledge gathered throughout the conversational interviews. The first version of the ecosystem map was then discussed with several team members of the healthdot venture team and supervisors from both Philips and TU Delft. This canvas was filled in together by hand or a proposal was shown digitally to receive feedback. The first version used to discuss can be found in appendix B. The outcome is shown in figure 12 and 13.

The table in figure 12 shows the different roles per stakeholder. An adhesive specialist supplies the adhesives of the healthdot. A pre-production facility serves as the manufacturer where the production line is. BioMeds are the biomedical engineers working in the hospital and Medical staff consist of doctors and nurses. The purchasing derpartment of the hospital and hospital direction play a role in decision making of ordering a new product. Forward and reverse logistic company is in this case the postal company. HSDP is the monitoring software that Philips provides. KPN provides the network infrastructure and POS Philips is the department where the order come in.

The ecosystem map in figure 13 shows the flow of the healthdot, money, services and intangible value between the stakeholders. The different rings show: 1) the users of the healthdot; 2) the different departments in a hospital which is the customer; 3) different Philips departments involved; 4) external companies involved.

Conversational Interviews

As mentioned earlier regarding medical consumables, the Healthdot is not the only (medical) device within Philips that needs to become circular. As there are multiple medical devices being designed and developed within Philips, the aim of group sustainability is to increase circularity for all of them. Therefore, throughout different projects and departments, Philips employees were interviewed to learn from other projects' success stories and challenges. Next to that, understanding what all needs to be considered is important for this project to be relevant for the company. To create this understanding, conversational interviews were held with 8 Philips employees.

Philips employees

- Senior product designer, Product design team
- Development Engineer, Product development team
- Lead product designer IGT, Product design team
- Business Analyst, Environment & Safety team
- Senior design researcher, design research team
- Customer service manager, Lumify business
- Circular Solutions , Group Sustainability
- Head Strategic Marketing, Chief Technology Office

Results

These interviews provided insights from different fields internally next to allowing to learn from pitfalls and challenges in other projects.

According to the development engineer from the Healthdot team, the PCBA used in the Healthdot is able to withstand 100-1000, considering the 14-day use cycles. This indicates potential for that component to be reused.

In line with the “safety-first” culture found in literature, there is a disposal culture in hospitals which might pose a challenge if hospital staff needs to be involved for reusing a device.

The Lumify business is one of the few business within Philips that has a refurbishing proposition up and running in the market. The customer service manager from that business indicated that for customers it needs to be clear who provides service when something goes wrong. Internally in Philips this also needs to be organized to provide good service to customers. This is important for the healthdot as it might impact the implementation phase, to set-up a dedicated person to service the hospitals.

The department head, purchasing employee, company director and biomedical engineers all have a role to play in decision making for aquiring a new product. This makes it more difficult if the hospital needs to be involved more.

If a takeback-system is necessary, then it needs to be designed upfront, before a product is redesigned or prepared for recovery. This provides the necessary urgency for figuring out how the Healthdot can become circular.

Stakeholder	Role
Adhesive specialist	Supplier adhesives
Pre-production facility	Manufacturer
BioMeds	Internal logistics hospital
Medical staff	Applying device to patient
Purchasing department hospital	Order placement
Hospital direction	Decision approval
Patient	Wear device after surgery
Forward logistics company	Ship devices to hospital
Reverse logistics company	Ship devices back to manufacturer
HSDP	Monitoring software Philips
KPN network	Network provider
POS Philips	Order intake

Figure 12 Stakeholders and their roles

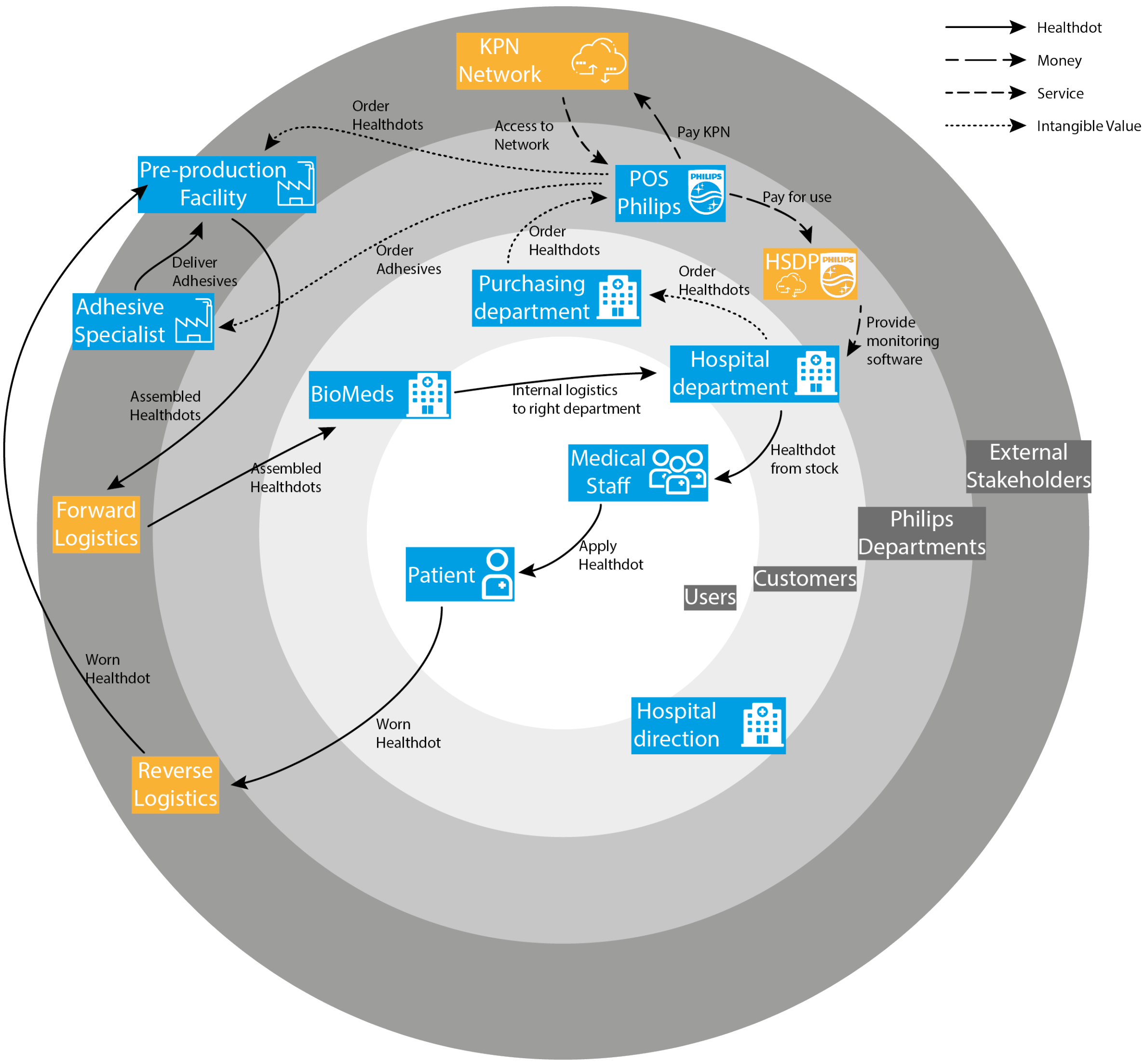


Figure 13 Ecosystem map

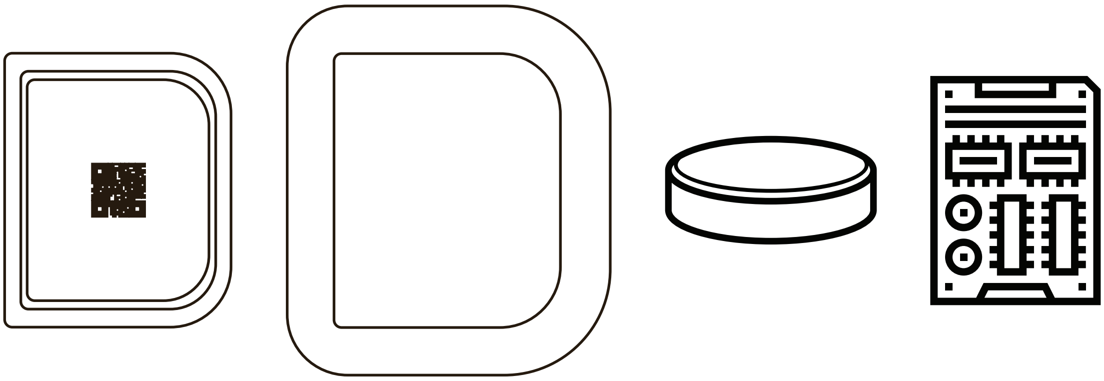


Figure 14: Components from left to right: Casing, Adhesive, battery, PCBA

3.2.2 Flow models

Here will be elaborated how the components assemble into the Healthdot and how the device then flows around in this ecosystem. The focus of the project is on implementation with the original scenario as a starting point. Therefore, the current product design is examined first in the flow model to see what components can be recovered for the first batch.

Since this project is exploring what strategy for making the healthdot circular should be aimed for and is not focusing solely on the product design, the product is discussed on a component level only. This means the components discussed are as follows: The adhesive part, the casing, the batteries and the pcba (figure 14). Going further into detail about different elements within the pcba or the adhesive would not add to the exploration and is out of scope for this project.

Obsolescence for the current version of the healthdot is the case after patients have worn it for 14-days. The current version of the device has multiple kinds of obsolescence after this 14-day period. First of all, the battery has died, creating technological obsolescence. Even if the device would still work, it's functionally obsolete for the patient who has worn it. Because a patient has worn the device, hygienic obsolescence is also applicable. The current version of the device cannot be used after the 14-day period anymore and is useless unless it is recovered.

The model

To uncover the opportunities for recovering the current version of the device an analysis of the Healthdot ecosystem is done with a model adapted from Lieder et al. (2017). With 4 components to discuss, this model serves as a good canvas to analyze and compare the original offer with future possibilities.

First the current version of the healthdot is put in de model (figure 15), in the original scenario without any takeback-system in place. Then a model is made with the current version of the healthdot including a takeback-system and reuse of the PCBA (figure 16). These are then mapped on the value hill model to assess the circularity. Finally a flow model is made showing the effect of improving circularity and the crucial aspects needed to enable a circular scenario.

On the left side of the model the manufacturing phase and recovery phase can be seen. Essentially this part of the model shows the activities and flow of components within the factory. The transport phase shows both the forward and reverse logistics. The use phase then includes every step from arrival at the hospital's internal logistics towards disposal or entering the reverse logistics stream. The arrows show how the component moves over time and throughout different phases.

Current version

The current version of the healthdot in the original scenario entails a workflow not focusing on reusing the device. In figure 15 one can see on a component level how they flow into the assembled product, towards the hospital. It then goes through the internal logistics of the hospital to end up in a departments stock. The nurses then pick it up from there when they need it. They pair it with the patient ID and apply it to the stomach of the patient. The patient wears it for 14 days after having the device applied to them. They go home while still wearing the device. After 14 days of wearing the Healthdot, the patient gets a reminder saying the device has stopped working and that they can remove it. They can dispose it in the

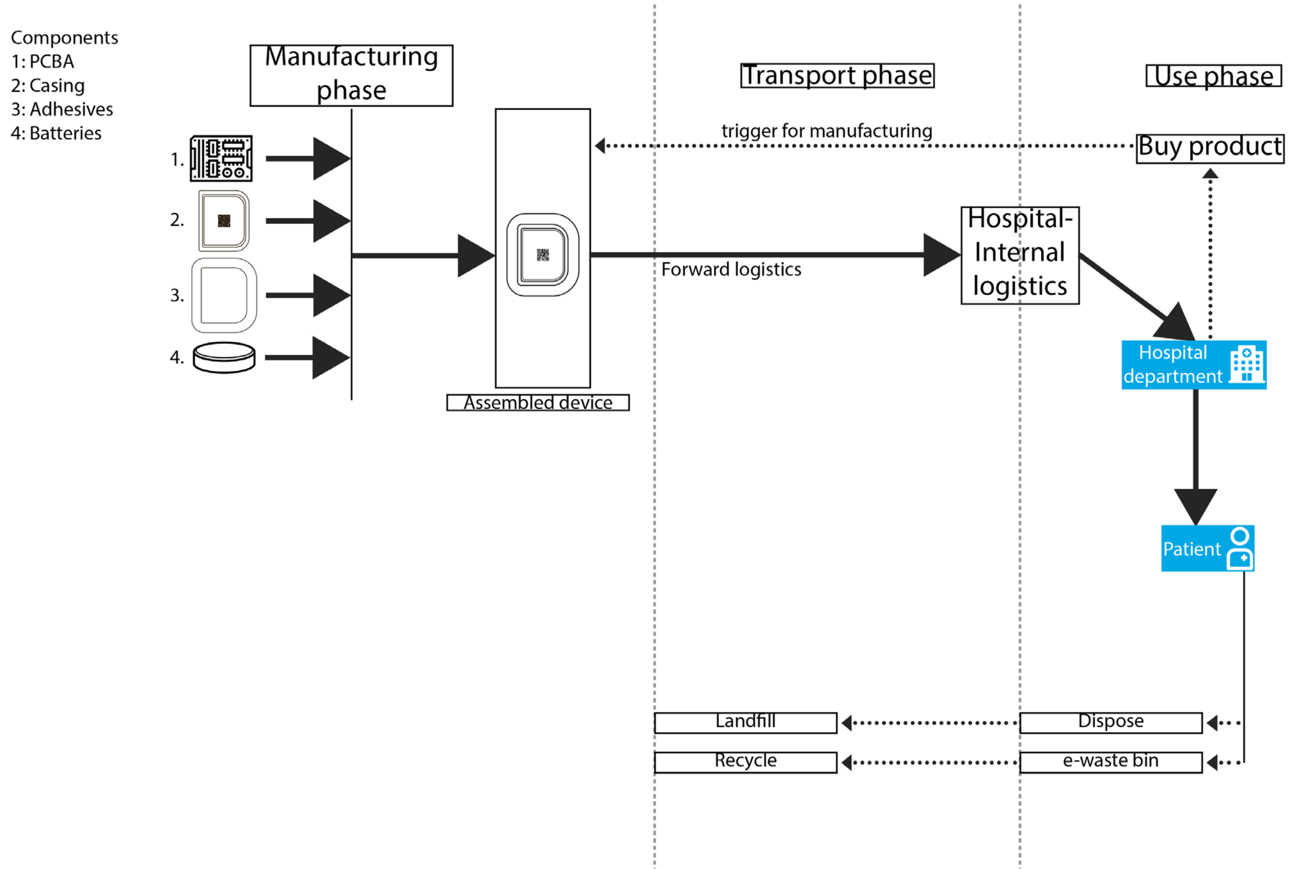


Figure 15 Flow model current offer

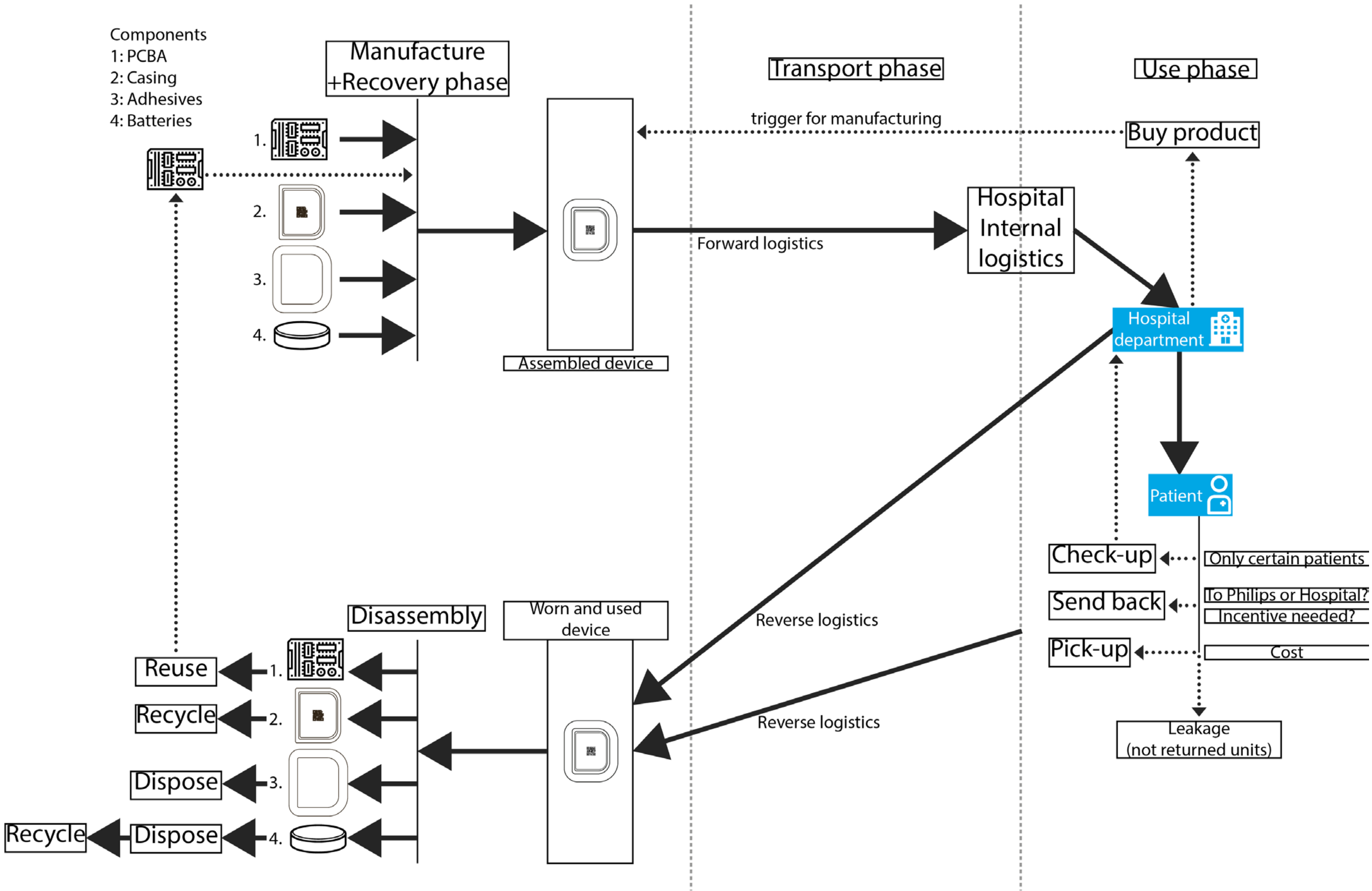


Figure 16 Flow model current design, including takeback system

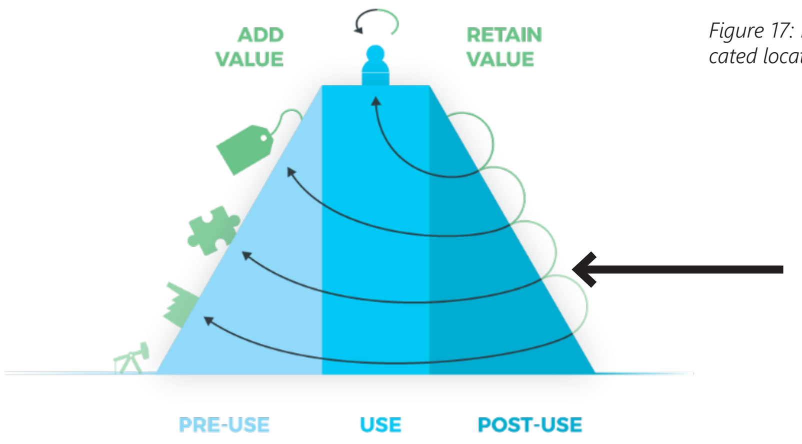


Figure 17: Reusing the PCBA enables a scenario at the indicated location on the value hill

e-waste bin at the supermarket or dispose it in their own trash bin at home (the latter is not desired but it's possible people will do this.) The hospital department will order products at Philips with a normal purchase order.

Recycling doesn't add to circular revenue so if Philips wants a product that adds to their ambitions, this is not a scenario that should be aimed for. Besides that, making sure people will actually dispose of it properly takes effort as well. When putting effort and costs into making sure people do the disposal correctly, it is clear that making them bring it to a correct disposal bin outside of their homes brings less value back to Philips as opposed to enabling Philips to retrieve the device and recover components that can be reused.

Reusing the PCBA

To make the healthdot offer circular, the loop needs to close. For the healthdot this means getting the devices back to Philips and reuse materials, components or the entire device. Figure 16 shows a flow model of the current version of the healthdot when it comes back to the manufacturer and the PCBA is reused.

For hygienic reasons, the adhesive part cannot be reused in its current state. The plastic casing in it's current state needs to be cut open the access internal components, therefore leaving the casing material available only for recycling. The PCBA in the current version can be reused, but the casing needs to be cut open to access it. The current version has batteries that only last for 14 days, after which they cannot be recharged or reused. Rechargeable batteries for example might be an option here to facilitate an improved redesign of the casing.

Value retention

To explain and assess the different options for closing the loop, the value hill (Achterberg et al., 2016a) is used. This provides a clear overview and shows visually the differences in value retention and effort needed for this retention. (figure 17 above)

The flow model shown in figure 15, is not desirable even if the device would be redesigned enabling every component to be fully recycled. The most circular loop is using the entire device again with the same level of functionality and as little as possible activities needed to use it again.

The healthdot in its current state, when recovered for disassembly, would allow for a "parts recovery" scenario. In figure 17 can be seen where that scenario fits on the value hill. This shows that from a circular perspective, there is room for improvement. The higher it can move up the hill, the more circular. To aim for an increase in circularity a CE strategy that is higher on the value hill should be taken. Reuse is not possible since it is only used for 2 weeks by a patient. That leaves a repair/maintain or refurbishment scenario. Seeing what would be feasible in terms of product design is to redesign the casing, use rechargeable batteries and only replacing the adhesive every use cycle. The flow model for this option shows a smoother back-end but also the crucial aspect of retrieving the device.

Redesign

The flow model shown in figure 18 gives an overview of a redesigned version of the healthdot. This indicates different activities in the recovery phase when a worn device arrives back at the factory. Any cleaning that would need to happen can be done with an alcohol

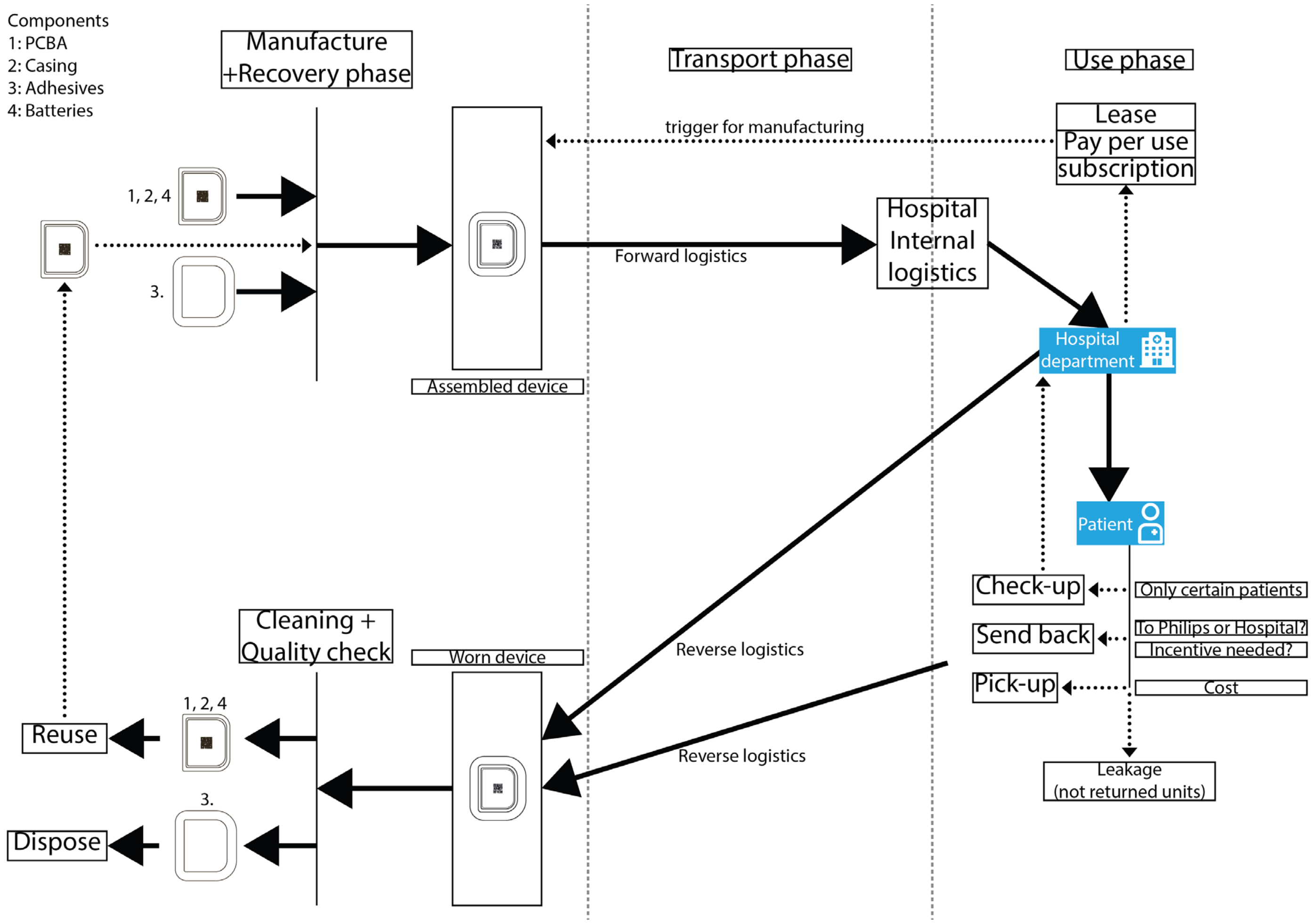


Figure 18 Flow model redesigned product including takeback system

detergent as the device falls in the non-critical category of Spaulding's scale (1968). See confidential appendix D for a full overview of this scale adapted for medical consumables.

LCA

It becomes clear that there are only two opportunities to follow in order to enable circularity within the scope of this project. Decreasing the environmental impact can be done in other ways, (think of working towards a biodegradable electronic circuit). This is however out of scope for this project as it requires extensive and in-depth knowledge of electronical circuits and would not impact the first batch of healthdots. The first option for enabling circularity can be done by retrieving the device and reusing the PCBA, according to the CE strategy "parts recovery". The second option is a redesign of the device enabling the CE strategy "refurbishment".

Based on the lifecycle assessment (LCA) of the another medical patch made by Philips, an educated guess can be made for the effect of reuse of different components. See confidential appendix E for the overview of this assesment. The patch with shows similarities with the healthdot in terms of components and because the results of the LCA are already available it serves as a good indicator. The results of this LCA show that reusing the PCBA can cut down 35% of the environmental impact that is caused in total by the patch. This is especially interesting since the PCBA is the component that can be reused after a use cycle with the current version of the design. Reusing the PCBA therefore makes the most sense to have an implementable plan for the first batch.

First Batch

The most promising opportunity to make the original offer of the healthdot circular is retrieving it after the patients have worn it, disassemble it and reuse the PCBA.

To increase the circularity and decrease the steps that are needed at the manufacturer to reuse the device, the healthdot would need a redesign. In chapter 6.1 will be elaborated on specific design requirements for this redesign increasing circularity.

Send back

It becomes clear that reusing the Healthdot, or any part of it, hinges on getting them back. This means that after patients have worn the devices for 14 days, the devices need to be retrieved. Either the patients can be asked/triggered to do this through regular mail or dropping it of somewhere, Philips can be proactive in getting them back through a pick-up service in some way, or the hospital plays a role in this. In any case of closing the loop, a takeback system needs to be in place. A seperate pick-up service is expensive to set-up and requires additional contracts with a logistics company. Besides that, an additional pick-up service is less environmentally friendly than using existing services or facilities. Therefore, only the hospitals role and patients role are analyzed in chapters 3.2.3 and 3.2.4.

While consumer electronics have a lot of unknowns in terms of who is using them (lack of registration, sold through multiple retailers) and when the product breaks or people stop using them, the healthdot has these aspects known. There is data about who wears the device, for how long and where the devices are. This makes retrieval much easier and gives the product more potential to set-up a successful takeback system.

It must be noted however, that dealing with this data needs to be done carefully due to privacy regulations such as the GDPR (General Data Protection Regulation) (EU,2019). The data is known by the hospital and patients give consent for the hospital to have access to the data. Philips however, does not have access without any consent from the patients. This means that either the data must be protected from Philips or patients need to give consent. The latter is not desirable as it might confuse people as to why they would be involved. But, giving consent can happen during hospitalization with an administrative hospital employee. Shielding the data from Philips can be done by automating the actions related to patients' personal data in the monitoring dashboard so that all data remains only accesible by the hospital.

3.2.3 Hospital

The healthdot offer is a B2B offer from Philips to Hospitals. Hospital employees in different functions come in contact with the device. Therefore several interviews with hospital staff were conducted.

Interviews hospital staff

The goal of interviewing hospital staff is to get qualitative insights on the clinical process of treatments, the added value provided by the Healthdot, the decision-making process in acquiring a new medical device, the feeling about medical waste, possible touchpoints in a hospital, and the possible role the hospital can fulfill in retrieving the Healthdots.

Set-up:
Two face-to-face interviews and three phone calls.
Duration of interviews: 30-45 minutes. Interview guide can be found in appendix C.

Participants:
5 employees in total with different functions and working experience ranging between 2 and 20 years. Two of the participants are also part of the pilot study conducted by the healthdot venture team and by the time they were interviewed had experience with applying a few healthdots to patients. Employees had the following roles:

- Biomedical engineer
- Anesthesist

- Clinical physicist
- Gastroenterology and liver specialist
- Oncology doctor, focus on stomach.

Results

The employees with clinical roles, all immediately expressed that they basically don't want to see anyone back again at the hospital. Usually this would mean there is either something serious going on and they need a check-up, or a complication has occurred in their recovery. Only certain patients do come back, but the timeframe in which this happens ranges from 2-3 weeks after surgery to 2-3 months or even longer. If all patients would need to come back to the hospital, (eg. to give back the healthdot) there won't be any capacity for this at the hospital.

In line with the value offered by the healthdot, hospitals want people out of there as soon as possible. This decreases costs and they feel pressured to start moving the care they provide outside of the hospital.
Hospital employees are aware of the huge amount of garbage that is produced. They feel guilty about it but don't know what they can do about it.

The healthdots get applied to patients when they are still a bit dizzy from surgery and happens when more devices get installed. Medical staff trust the devices they use, and trust that the devices are at the place where they need them, when they need them. This trust comes from the clinical staff relying on biomedical engineers who are responsible for the equipment.

If hospital employees throw stuff away, it's mainly medical staff. The maintenance and quality checks are done by the biomedical engineers. The Healthdot returning to the hospital therefore might not be an issue in terms of the "safety-first" culture when there are clear instructions on how to deal with the device. However, it is crucial to make sure that all decision makers for the new product agree with the requirements set by Philips.

The interviews showed that the hospital wants patients to move out of there as soon as possible. If the devices would return to the hospital, hospital staff would have to take care of the devices. This means extra effort for the hospital staff if Philips would try and make the healthdot more circular in this way. All options of the hospital being involved in retrieval of the Healthdot from patients is in contrast with core elements of the Healthdot's value proposition. These are simplicity for the hospital and enabling them to move the care they provide out of the hospital. Hence, the hospitals role is limited and not a desirable option for circular Healthdot.

3.2.4 Patients

The patients who will be wearing the healthdot are crucial when it comes to reusing the device. The patients with potential for out of hospital monitoring consist of different demographics. Ages vary between 20-80 with the majority being between 45-65. (CBS, 2014) Different illnesses and diseases have different limitations for patients after surgery. A certain surgery might cause a patient to remain in bed for a week after the surgery whereas another patient undergoing a different surgery may be able to walk on his or her own the next day. Indicated by a surgeon during a presentation at the Philips office, medical staff sometimes has to take 20 to 25 additional conditions into account while treating patients needing the same type of surgery. This means the potential users are within a very widely spread and differentiated group of people, that might have complex medical profiles.

The main types of surgery currently targeted by the Healthdot team are abdominal surgery and invasive cardiac surgery. In confidential appendix C a table can be found with more applicable conditions for the Healthdot.

Insights regarding the patients are obtained in multiple ways. Several people are interviewed in a semi-structured interview to learn about their experiences throughout a surgery and recovery. A pilot study done by the venture team provides some insights as well. However, as this is an ongoing study, the insights gathered are not very concrete yet but are a bit more superficial. These add to the overall understanding of the patient experience of recovering from surgery.

Interviews patients
4 Face to face semi-structured interviews, held at participants' homes. 1 Skype call. Duration of interviews ranged from 30-60 minutes. Interview guide can be found in appendix D.

5 participants, Age between 26 – 59. Underwent different types of abdominal surgery and one broken leg surgery.

Interview results and discussion
The people supporting patients during their recovery are crucial. They play a big role in the whole recovery experience. During interviews often the partner involved could provide additional insights and turned out to be of great support both physically and mentally. Participants had someone staying over at their homes to take care of them, a partner that was continuously there for them or stayed at family who would then take care of them.

Information that is currently provided at the moment of discharge is too general, sometimes confusing or contradictory and provided partially verbally and partially written. The interviews made clear that information provided differs a lot. Written information varies from a brochure about the specific surgery that partipants underwent, while another got a flyer with information on surgery at a hospital.

Verbal information is more difficult to remember but is perceived as valuable as it is communicated personally. This information however can differ per doctor or nurse and one participant even got completely contradictory advice from two different doctors.

Participants indicated a moment of closure is missing. Part of this was about confirmation of knowing when they are actually better, while another aspect was having a clear moment when a certain phase was over.

Customer journey map
Based on the insights gathered in the interviews a customer journey map was made. The goal of a customer journey map is to identify pain points and opportunities for intervention. During the interviews participants were provided with an empty journey canvas to support making a journey map. This canvas can be found in appendix E.

The customer journey map can be seen in figure 19 on page 46 and 47. It shows the experience of patients in the current situation without the healthdot. It starts at the moment they feel pain, are diagnosed by their doctor and ends with the final check-up after recovery, at the doctor.

Personas

The personas created are based on the insights obtained through the interviews, some stories form hospital employees and internal documentation from Philips about patient types.

The three different personas shown are made to serve as a source of inspiration for the design phase later in the project. They are used to provide an understanding of patients' burdens to participants of a creative session in chapter 5.1.1. The personas entail three different patients, that have different ways of living and underwent different types of surgery. They all have different needs for advice and value different things in life. The personas can be found in appendix F.

Current journey map

Journey map showing the experience of patients that underwent different types of abdominal surgery. It is shown from the moment of pain towards final check-up at the doctor.

Setting	Pain/diagnose	Hospitalization/ Surgery	Wake up/first night or hours

When and what involved	At home, at work or anywhere in between,. Then go to GP office	In hospital, hospitalization happens either through ER or doctor reference	Wake-up in general ward or Intensive care depending on surgery. Can be anytime during day

Thoughts

Emotion

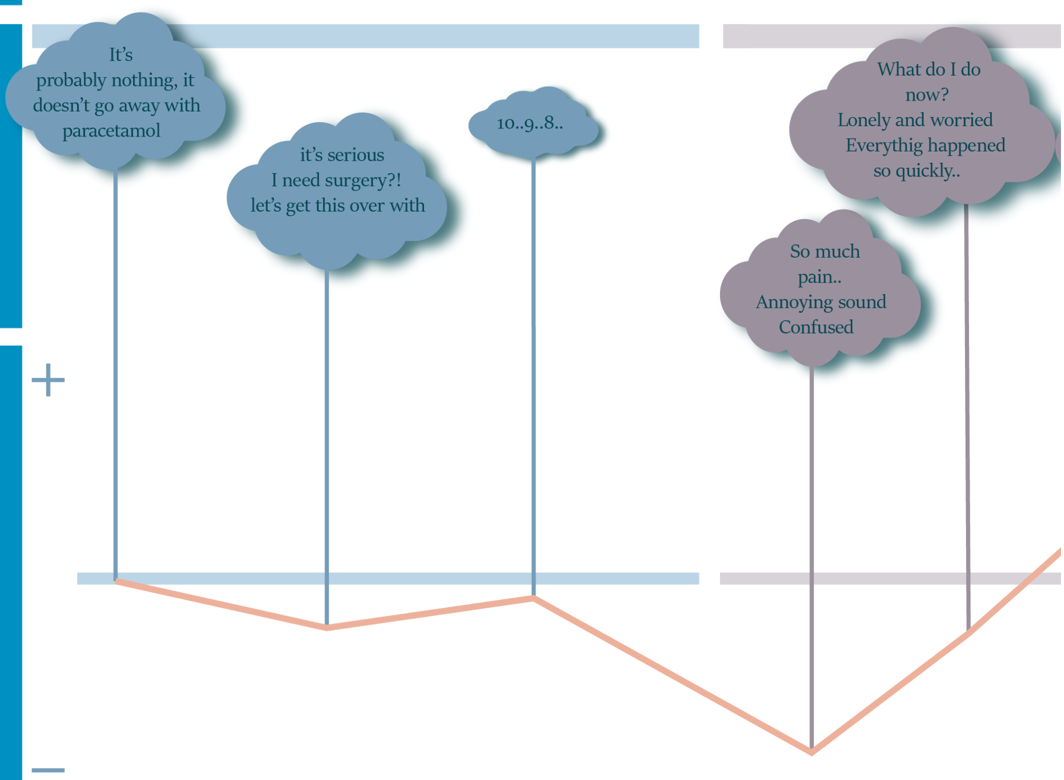
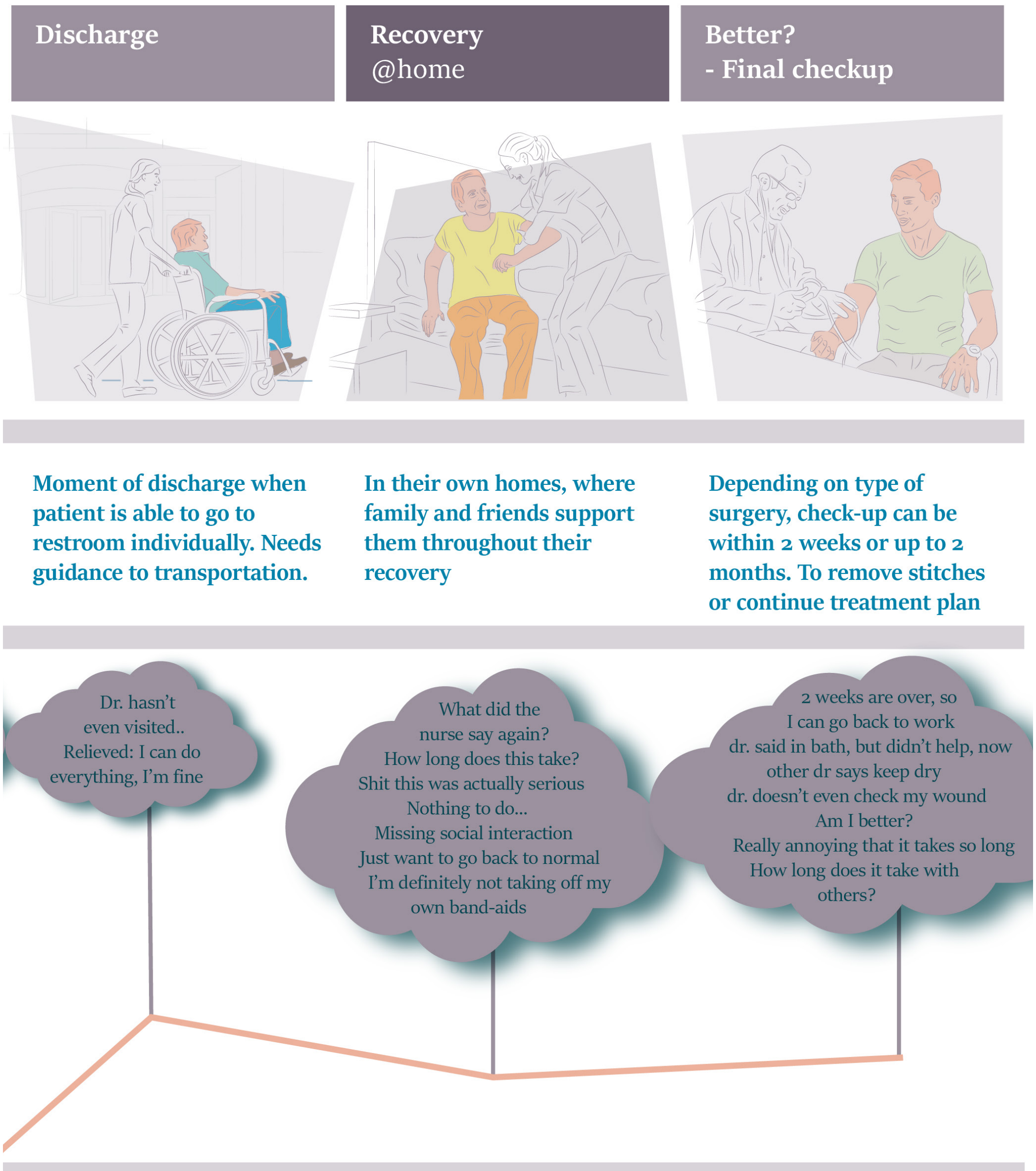


Figure 19: Customer journey map abdominal patients



Opportunities for a circular Healthdot

The current version of the Healthdot can become circular to some extent. The PCBA can be reused, which is especially interesting since it is the most expensive component with the highest environmental impact.

Circularity can be increased as reusing the PCBA enables the “parts recovery” strategy. To increase value retention a feasible redesign of the Healthdot would enable the casing including PCBA and rechargable batteries to be reused. Then only the adhesive part needs replacement. This would enable a “refurbishment” strategy.

For both CE-strategies it is however crucial that the Healthdot is retrieved from patients after the 14-day wearing period.

Opportunities to retrieve Healthdot

Hospitals play a big role in developing the proposition. Their focus is on proving care to their patients. They feel pressure to move care out of the hospital which requires a change in the relationship they will have with their patients. The role hospitals can play in retrieving the Healthdot is limited, as they don't want, or have the capacity for, many patients coming back.

Picking up the device at patients is costly and requires an additional pick-up service. That leaves patients sending back the device as most promising option to retrieve the Healthdot.

Patients however, are mentally and physically burdened. In general, recovering from surgery is not a pleasant experience. The current patient experience shows several pain points in receiving scattered and general info, missing guidance or confirmation during recovery. Additionally, family and friends of the patient play a big role in their recovery period, whom could be used as well.

For the Healthdot this means that improving the patient experience during their recovery period at home is the way to enable a circular offer.

Design Brief

In this chapter the analysis is synthesized according to three preconditions motivation, ability, trigger and the Create-Action funnel. It serves as an overview and bridge between the analysis and the design phase.

For all three preconditions is specified how they are not present in the original offer and what exactly is the opportunity to improve. The problem is summarized and the design challenge is framed on two focus points: patient engagement and the device itself.

Finally, a list of requirements is framed from the perspective of the hospital, Philips business, patients and the environment.

4 Design Brief

4.1 Problem Summary

Within this chapter the analysis is synthesized into a design challenge with a list of requirements from different stakeholders.

During their recovery, patients are busy with getting better. They have physical limitations in terms of mobility. They are sitting at home, being sick, and just want to get better which is a burden mentally as well. Parts recovery or refurbishment can be enabled by retrieving the Healthdot. Patients need to send back the device after they have worn it for two weeks. However, it's not about getting healthy people to perform a particular behavior, but people who are sick and busy with something else entirely. The "simple" act therefore, is not so simple.

The analysis showed the specific pain points during patient recovery. How they form opportunties will be explained by aligning them with Fogg's behavior model. All three necessary preconditions by Fogg (2009) are not present in the original scenario for patients. There is low motivation, low ability and no trigger.

Motivation
The device has no added value for the patient anymore after removal, therefore their motivation is rather low. After the 14-day activity of the Healthdot, the device stops working. There is no pleasure motivator for patients as the device becomes useless for the patients at this point. They need a reason to act and currently there is non. The corresponding side 'pain' is also not present as there is no consequence if they don't send back the device. This makes it also easy to forget.

Even though family and friends are involved during the recovery period, there is no sign of social acceptance motivator.

With regard to the partner of the patient or other loved one involved, there is also no motivation present. Rather another task for them to do. When the patient asks them, social acceptance might be a motivator but otherwise there is nothing motivating them.

The reason for sending back the device is unclear and not showing patients how they contribute to either the environment, helping other patients or help the hospital in using less equipment by sending back the Healthdot. Sending back the device might create fear of sending back "their" data. It is not explained to patients how that is not the case, which serves as a negative motivator.

The opportunity to increase motivation is by providing an improved experience for patients. Adressing the pain points in the current recovery experience such as scattered, general and sometimes contradictory info, lack of personal contact or the lack of confirmation and closure during recovery might provide the pleasure motivator for the target behavior. Another opportunity is addressing their partner or other loved one helping them during recovery more to increase the social factor.

Ability
Although patients have time available, all other ability aspects are not present. They have high physical inability due to their surgery. This also means the mental burden of being sick which decreases their ability further. This especially limits their ability considering there currently is no guidance and clear information on returning the device.

It costs money to send back, patients would need an envelope and stamps. This might prevent them from doing it. Even though sending a card with regular post might be familiair, sending a band-aid like medical device is something new for them thus more difficult.

The interviews with ex-patients show willingness to send back the devices or ask someone who is supporting them, to send it back when it is easy to do and free of charge.

Increasing the ability to send-back the device can therefore be be done by creating a facilitator making it as easy as possible for the patient or their caretaker. This means both preventing them from forgetting to act at the right moment as well as providing instructions or materials to send back the Healthdot.

Trigger
Even if the motivation is there and the patient or their caretaker is actually able to perform the behavior, doesn't mean they will do so (Fogg, 2009). Currently there is nothing present to increase either of the above preconditions. There is no spark present to increase motivation, no facilitor present to increase ability and a signal in itself won't be sufficient as both motivation and ability are too low for the behaviour to occur.

In order for someone to actually perform the desired behavior of sending back, they need to be triggered. The moment for action is when the device is removed. Therefore they need something triggering them to act during that moment.

The core challenge for patients and/or their "caretaker" to make a circular decision is when the device is removed from the patients' stomach. Similar to what happens with information they currently receive, they are likely to place the device somewhere and loose it or dispose of it if nothing is done right away, according to the interviews conducted. Therefore, any later attempts to send it back needs more effort, if they still have the device, as they now also need to find it, and figure out how to send it. This makes timing a crucial aspect in performing the send back behavior.

In order to understand the above elements in chronological order they are put in the steps of the Create-Action funnel (Wendel, 2014):

1. There needs to be a cue or trigger that makes either the patient or caretaker think about sending back the healthdot around the moment of removal.
2. This cue needs to feel logic for them and create a positive reaction to it
3. The action needs to feel relevant for them so when evaluating the idea of sending back they need to feel that it is okay for them to do so.
4. They check if it is easy for them to do and if they actually can do it. This can be enabled by providing clear instructions and the materials needed would make it easier.
5. They determine if there is an urgency to send back the Healthdot and if they need to act right away. This means there should be something indicating when they would need to act.

Design Challenge
The core elements of the design challenge are two-fold. One part targets the product and the other targets the patient engagement.
With all three preconditions not present or very low, it is very likely that patients won't send back the Healthdot. The opportunities existing for all of them to be present and the target behavior to happen, result in the following elements that make the design challenge:

Product:
- Extend product life of the Healthdot (through multiple use cycles)
- Reduce medical waste

Patient Engagement:
- Improve patient experience during recovery
- Provide clear and personal information
- Give closure and confirmation to patients
- Make it as easy as possible to send back
- Involve partner or other friend/relative in the process

4.2 List of Requirements

As the Healthdot offer needs to satisfy many different needs of they are categorized for the main stakeholders. The requirements listed are obtained through desk- and field-research earlier in the project and checked with stakeholders involved. These will be used to design with and determine in what way steps in the service blueprint can be improved.

Environmental

- reduce (medical) waste by enabling reuse of parts of or the entire device
- decrease the amount of resources needed by reusing device
- Move towards a fully closed loop
- Reduce ReCiPe ecoscore and carbon footprint

Hospital

- The design does not add complex actions in the nurse workflow
- The design increases amount of patients that won't have to come back
- The design improves the relationship between hospital and patient
- The offer enables the hospital to operate more sustainable without additional hassle in device handling

Business

- The design is easy to implement and feasible already for the first batch
- The design increases patient engagement after leaving the hospital
- The design increases control regarding fleet management
- The design decreases total cost of operation and is not costly to implement
- The design maintains one of the core values of the venture; "simplicity"
- The design enables the device to add to circular revenue as specified by Philips
- The design explores Consumables as a service

User

- The design makes it as easy as possible to send it back
- The design provides clear instructions and avoids hassle
- The design stimulates involvement of a partner or friend
- The design provides personal info in a clear manner
- The design makes the patient feel cared for at home
- The design emphasizes a clear urgency for sending back the device
- The design emphasizes the device physically moving out of their homes to provide closure

Design Development

The goal of this part of the thesis is to show how the design brief in chapter 3 leads to a service concept that accomplishes the objective of the project: "Engaging patients to send back the device after wearing it in order to enable a circular offer for the Healthdot."
The first part of the chapter elaborates on the ideation that took place and how the result of that became a concept. The second part then explains the detailing of that concept to set it up for validation and shows the insights gathered.

During this phase in the project several methods were used to create ideas and frame them into concepts. Brainstorm session, creative session driven by How-Might-We questions and the value proposition canvas are used. Then this was conceptualized using the Service Blueprint. A qualitative study was conducted to validate the concept, which provided insights leading to the final concept.

5 Design Development

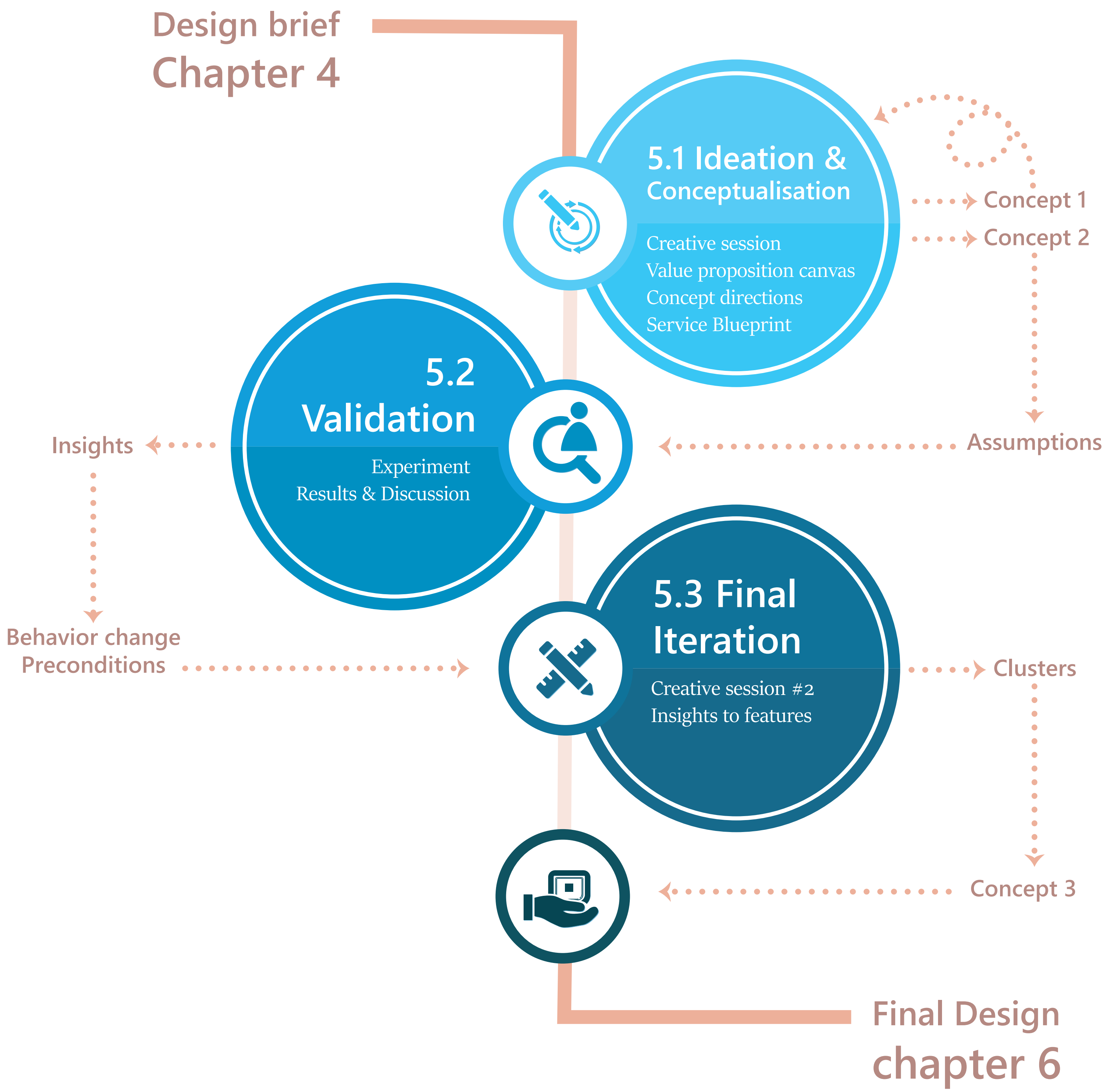


Figure 21 (right page): Value proposition canvas based on Strategyzer's canvas (Strategyzer, 2019)

5.1 Ideation & Conceptualization

5.1.1 Creative session

The starting point for design development was a creative session with design students (figure 20). This ideation session focused on inspiration and starting points for conceptualization. Five design students participated. The participants were shortly briefed on the context and taken through the customer journey map of the patient experience, and three personas were used to emphasize the condition of patients. They were then introduced to 4 design challenges framed into "How Might We" questions:

- How might we motivate and trigger someone to act and actually send back the device?
- How might we emphasize the accomplishment of reaching the end of the first recovery stage?
- How might we provide the send-back material to the patients home to feel like a gift?
- How might we provide the send-back material to the patients home in a branded package emphasizing closure of a recovery stage?

Based on these questions a brainstorm session followed per question. Two ideas formed which were worked out more elaborately. These can be found in appendix G. The core elements are as follows:

- Patients become part of an online community when receiving the healthdot in the hospital. This community would then support the patient in returning it when it's time to return the device.

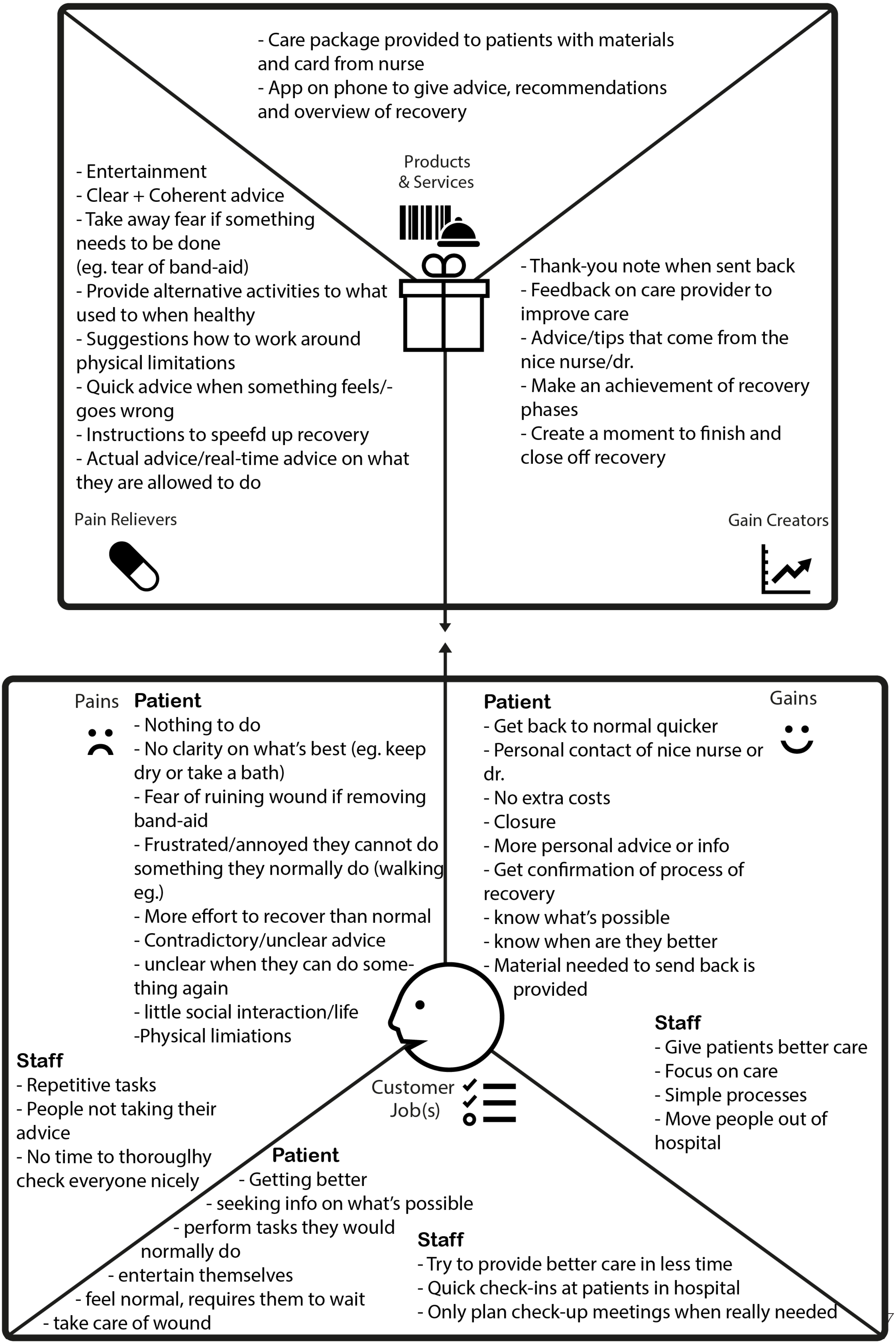
- Patients receive a package with a story about the patients that recovered because of the healthdot. This would then motivate to send it back to help other patients to recover.

Figure 20: design students ideating on design challenges

5.1.2 Value proposition canvas

The value proposition canvas is a tool that can be used to ideate on specific elements that cause pain points for a user. With this canvas, the customers jobs, pains and gains can be directly translated in gain creators and pain relievers. Following this, these creators and relievers can be combined or connected in a product- or service concept.

Due to the multiple end users involved dealing with the healthdot, the canvas is made with both patient and medical staff's perspectives. The ideas from 5.1.1 are put in to specify elements that serve as a solution for the pains and gains found in the analysis. One concept is then selected by assessing options with the design requirements from the design brief. On the next page figure 21 shows how all perspectives were merged into one canvas. The bottom part of the canvas contains the pains, gains and jobs of both patients and medical staff. The top part shows solutions for these and the ideas for a service.


- Care package provided to patients with materials and card from nurse
- App on phone to give advice, recommendations and overview of recovery
Products & Services
- Entertainment
- Clear + Coherent advice
- Take away fear if something needs to be done (eg. tear of band-aid)
- Provide alternative activities to what used to when healthy
- Suggestions how to work around physical limitations
- Quick advice when something feels/-goes wrong
- Instructions to speefd up recovery
- Actual advice/real-time advice on what they are allowed to do
Pain Relievers
- Thank-you note when sent back
- Feedback on care provider to improve care
- Advice/tips that come from the nice nurse/dr.
- Make an achievement of recovery phases
- Create a moment to finish and close off recovery
Gain Creators
Pains
Patient
- Nothing to do
- No clarity on what's best (eg. keep dry or take a bath)
- Fear of ruining wound if removing band-aid
- Frustrated/annoyed they cannot do something they normally do (walking eg.)
- More effort to recover than normal
- Contradictory/unclear advice
- unclear when they can do something again
- little social interaction/life
-Physical limiations
Staff
- Repetitive tasks
- People not taking their advice
- No time to thoroughly check everyone nicely
Patient
- Get back to normal quicker
- Personal contact of nice nurse or dr.
- No extra costs
- Closure
- More personal advice or info
- Get confirmation of process of recovery
- know what's possible
- know when are they better
- Material needed to send back is provided
Gains
Staff
- Give patients better care
- Focus on care
- Simple processes
- Move people out of hospital
Customer Job(s)
Patient
- Getting better
- seeking info on what's possible
- perform tasks they would normally do
- entertain themselves
- feel normal, requires them to wait
- take care of wound
Staff
- Try to provide better care in less time
- Quick check-ins at patients in hospital
- Only plan check-up meetings when really needed

5.1.3 Concept directions

The concept direction coming out of the creative session and value proposition canvas is described below before moving on to conceptualizing it further in 5.1.4.

Concept: App with reuseable packaging

The concept coming out of creating the value proposition canvas consists out of a Healthdot app for the patients and reusable packaging for the Healthdot.

Patients would start using the Healthdot app right before discharge. The app allowed to reward and engage the patients with insight in their data that was being gathered by the Healthdot. Through the app the patient and hospital could communicate throughout recovery allowing the patient to also ask questions.

With the app there is the opportunity to update and include multiple functions. This therefore seemed the idea with most potential and was used for further development.

This concept was placed into a rough service blueprint which can be found in appendix H. The service blueprint is used to communicate and gather the first feedback on the concept. After consulting several employees it quickly turned out to be overlapping with other enormous projects within Philips regarding communication platforms and medical apps for patients. To keep the focus on implementation it is determined that a simplified version has more potential to affect the first batch of Healthdots.

Concept: Messaging & package

Based upon the feedback gathered on the previous concept, the painpoints such as the patient installing an app during discharge and technological illiteracy of the aged target group, the second concept is made. This concept will be elaborated in detail in chapter 5.1.4.

Due to the technical illiteracy of the target group the SMS medium is chosen for communication. This is a basic channel that only requires a mobile phone, hence increasing the chances of smooth contact. Next to this, gathering feedback on the previous iteration, the ongoing projects within Philips regarding communication platforms make it redundant to start such an initiative for a single case. The realization of those platforms takes longer than the planned release of the first batch of healthdots, making a bridge between integration in a platform and affecting the first batch a necessity. The target group for this concept are “carepairs”. These are patients that have a partner or someone else supporting them throughout the recovery period.

5.1.4 Service Blueprint

Both as a means to improve the concept as well as mapping and communicating the concept the Service Blueprint is used as a tool.

The blueprint containing this concept, is used to obtain feedback from different perspectives. In informal conversational settings it is discussed with several Philips employees as well as the TU Delft supervisors. Due to the needed perspectives within Philips being scattered throughout different departments and locations it is discussed in separate 1-on-1 meetings.
The blueprint is visible on the next pages and the concept will be elaborated in the following paragraphs.

The patient's experience starts at the moment of hospitalization. The concept mainly starts affecting the experience after the patient has had surgery and focuses on their recovery period at home. During the moment of discharge they receive verbal explanation about their recovery and the functioning of the healthdot and sending it back. The carepair is briefly informed about receiving text messages and a package.

The carepair will receive text messages and a package by post. This will be similar to an unboxing experience, but then reversed. A packing experience.

During the recovery period at home, the patient receives text messages from the hospital that are adressed to them. The messages serve a different goal throughout the recovery period. The first message opens the line of communication. The second message aims to feel like advice provided by a doctor. Thirdly, the final message provides clear instructions to manage expectations. Below are the messages shown.

On the day of discharge they will receive the first message: Message #1:
Hi [Name],
We hope you got home safe! All the best from the nurs team at hospital [Hospital name]

On day five after discharge the patient receives the second message. Message #2:
Hi [Name],
Hopefully you are being taken care of well at home!
If the pain allows it, you could start and try some calm activity. All the best from the nurse team at hospital [Hospital name]

On day 10 after discharge the patient receives the third message Message #3:
Hi [Name],
Within the next days you will receive a package from us. This includes instructions for removal and send-back of the healthdot.
All the best from the nurse team at hospital [Hospital name]

Around day 13 after surgery, they will receive a package by post. This package will include an overview of the data collected by the healthdot, a thank-you card for their personal caretaker (family/ friends) and a return "envelope" for the device itself. With this return "envelope" also come instructions for removal of the device and sending back. The intention is that patients receive the package, open it and follow the instructions.

The data overview shows a timeline of the recovery period and compares their data with the standard for their surgery and the average of others.

Support systems

In order to support this entire service, several systems are needed to make it work. The bottom row of the blueprint shows the systems needed at different stages of the service.

The blueprint does not show what happens before the moment when the healthdot gets applied to the patient. This is briefly described here.

The healthdot gets manufactured. It is packed and shipped to the hospital. Upon arrival at the hospital it goes through internal logistics to the correct department. There it will be stored and ready for the nurse team of that department to use.

Service blueprint

The service blueprint provides an overview of different layers describing how the service works.
It starts at the moment of discharge and ends when the patient closes the first stage of recovery

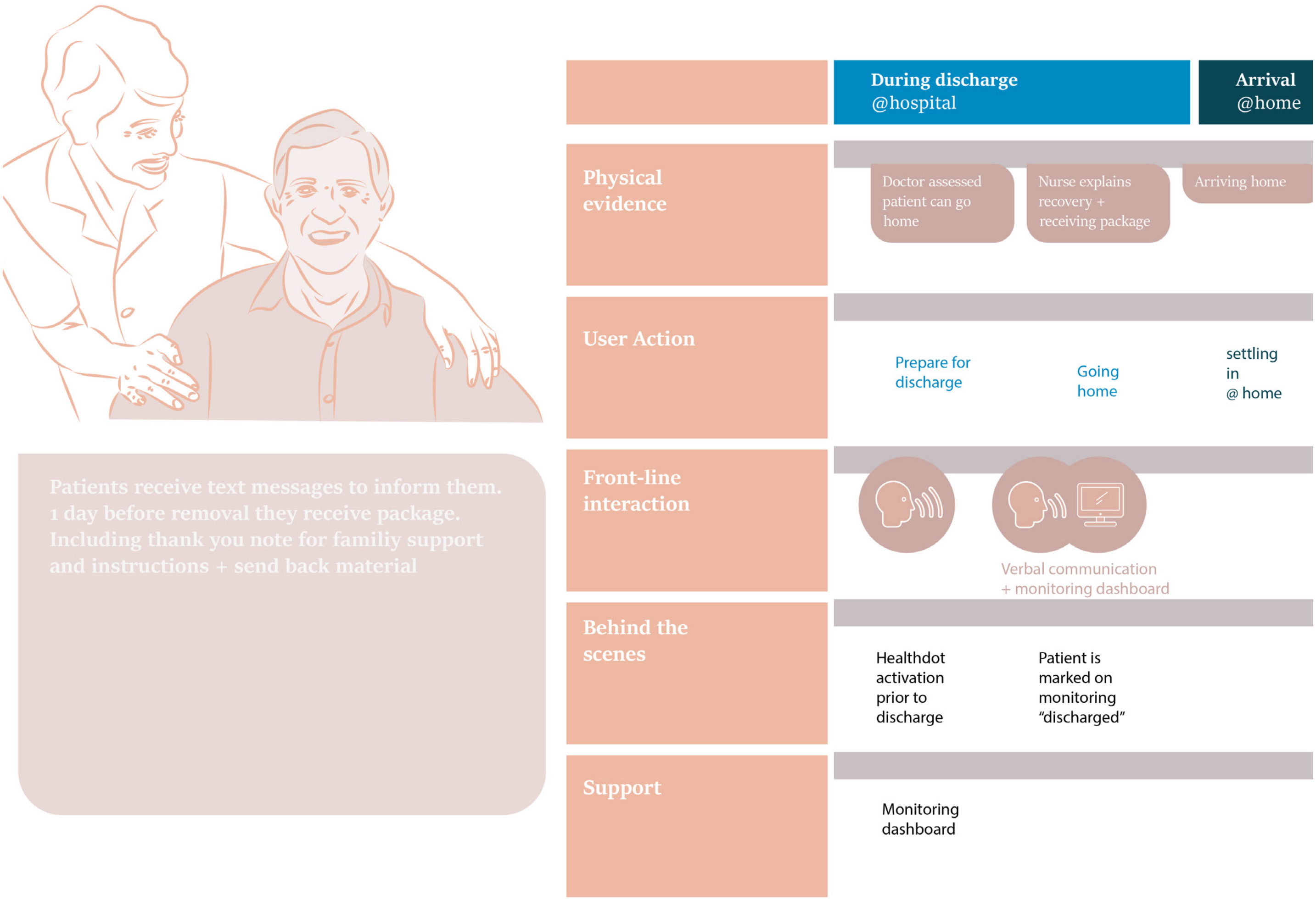
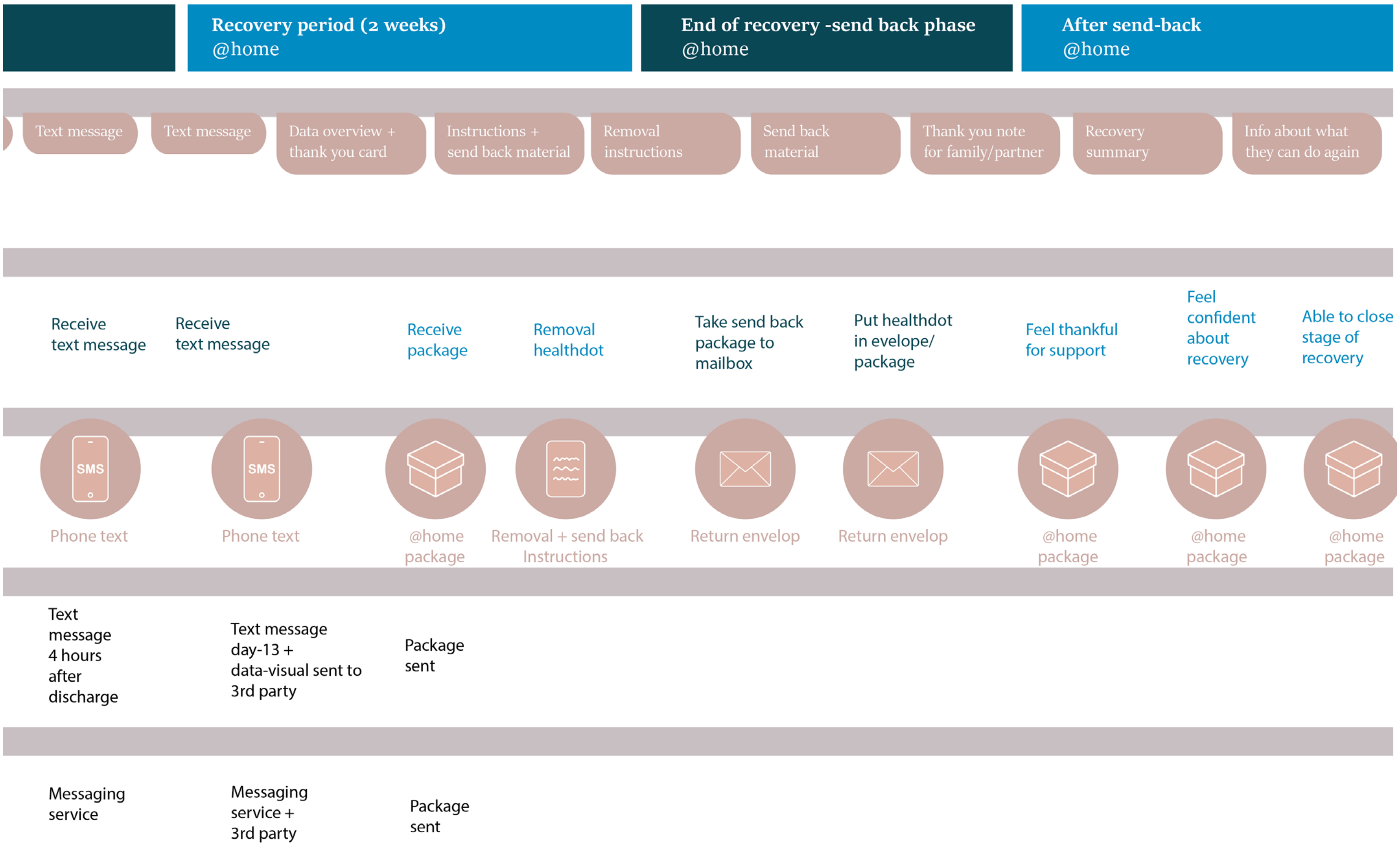


Figure 22: Service Blueprint


Recovery period (2 weeks)
@home
End of recovery -send back phase
@home
After send-back
@home
Text message
Text message
Data overview + thank you card
Instructions + send back material
Removal instructions
Send back material
Thank you note for family/partner
Recovery summary
Info about what they can do again
Receive text message
Receive text message
Receive package
Removal healthdot
Take send back package to mailbox
Put healthdot in evelope/ package
Feel thankful for support
Feel confident about recovery
Able to close stage of recovery
SMS
SMS
Phone text
Phone text
@home package
Removal + send back Instructions
Return envelop
Return envelop
@home package
@home package
@home package
Text message 4 hours after discharge
Text message day-13 + data-visual sent to 3rd party
Package sent
Messaging service
Messaging service + 3rd party
Package sent

When a patient is registered for surgery, there is a log in the system that the patient will receive a healthdot after surgery. After surgery in the recovery room, a nurse pairs a healthdot with the patient id. The healthdot then gets applied to the stomach of the patient.

When the patient goes home, it will keep wearing the healthdot until they have been wearing it for 14 days in total. After this period the batteries run out and it's of no use anymore to the patient.

Philips

Philips is the manufacturer of the device and is the party that requires the devices back for value recovery. Therefore they will provide the messaging and package within the healthdot offer to the hospital. It will seem like the messages and package come from the hospital in the patient's eyes, hence improving the care the hospital can provide.

Hospital side

The hospital obtains the healthdots, including its monitoring system from Philips. The system includes the messaging functionality and package. At the moment of hospitalization an administrative employee makes sure the patients personal data is correctly in the hospital system (EMR). The nurse interacts with the healthdot monitoring dashboard.

5.1.5 Prototyping

Different elements of the concept where made into tangible artefacts to explore content, visuals and prepare for validation in chapter 5.2. The next paragraphs explain how each element is imagined to increase either motivation or ability for the patients.

Package

The package provided to patients in this concept consists out of istructions, an overview of monitored data , a thank-you card for the partner and the return envelope.

The package is intended to arrive at the patient briefly before they need it. The timing of this and the clear instructions with return envelope aim to decrease the mental and physical effort it takes to send back. With this the ability to perform the desired behavior of sending back the healthdot should increase.

The data overview and thank-you card serve different functions. The data overview is intended to provide pleasure to the patient that they are able to see the process of their recovery. The thank-you card aims to include the partner more during the moment of removal and provoke a social element in sending back the device. Both the overview and card are then a spark increasing motivation to perform the desired behavior of sending back the device.

Messaging

The text messages sent to the patient throughout the recovery period mainly aim to serve as a signal trigger. On the other hand the messages are intended as a way to stay in touch with the patient, and show that they are not forgotten. The messaging thus serves partially as a spark to increase motivation but also as a ongoing signal trigger.

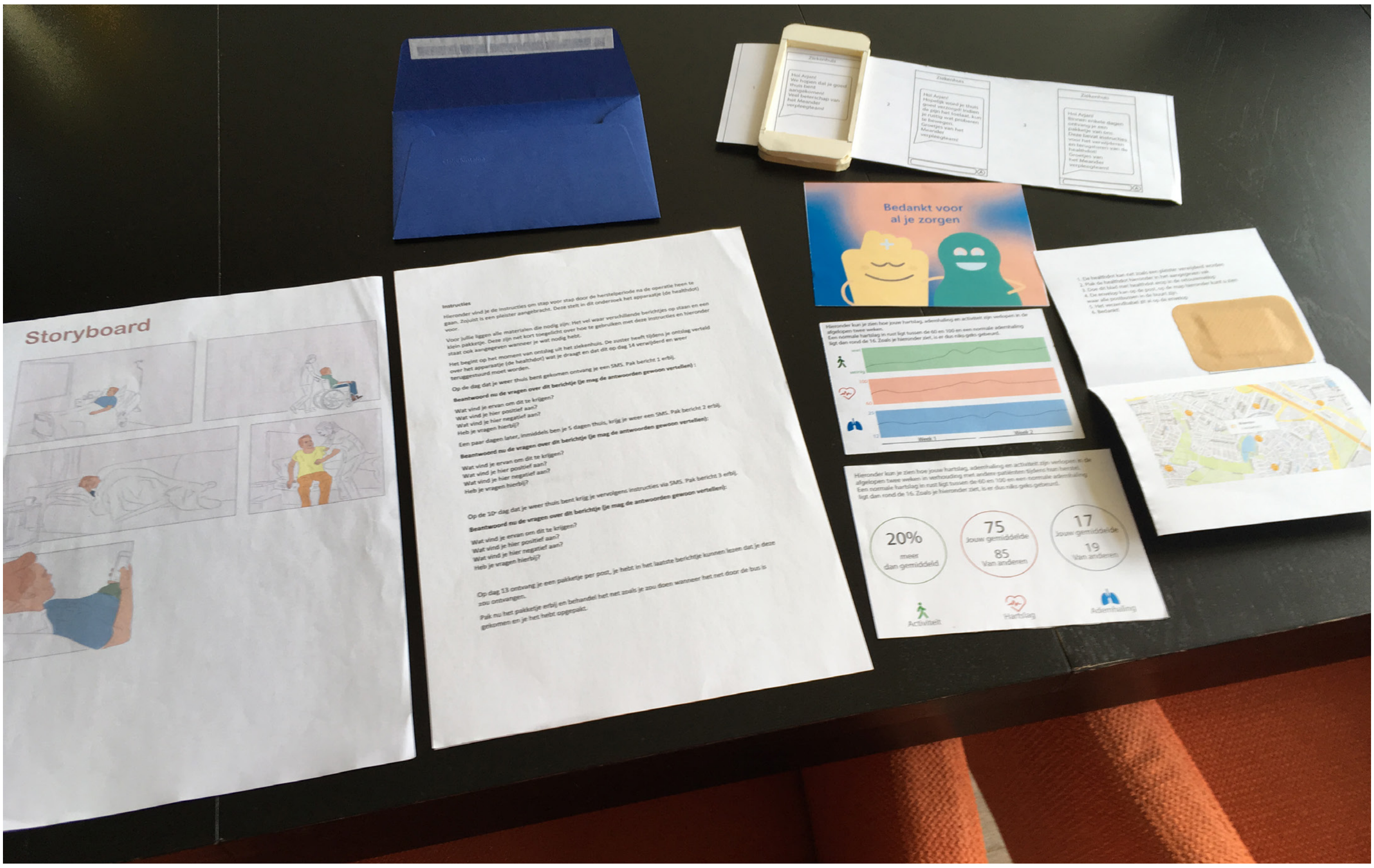


Figure 23: All materials provided to participants

5.2 Validation

5.2.1 Experiment set-up

The qualitative study aims to investigate how the concept influences the send-back process and recovery experience. As a circular healthdot hinges on its return, patients need to send it back. To motivate and facilitate them to send it back it is important that it is easy and rewarding due to their physical and mental burdens.
To understand the effect of different elements on motivation (rewarding) and ability (easy), each touchpoint for the patients is questioned after interaction. This allows for asking the patients why they perceive something as rewarding or meaningful.

Research question:
How do different types of triggers on motivation and ability influence the experience and behavior of the patient and their caretaker around the moment of removal of the healthdot?

The predicted outcome is that the physical package and text messages are rewarding for patients by providing feedback on recovery and make it easy for them to send back the device.

Participants
As the concept is aimed at patients that have support from a partner, family member or friend during recovery the participants for the study are as follows: 6 Healthy people that have had surgery in the past, including their personal caretaker. These are called carepairs.

Materials
- Paper prototype of phone screen with text messages
- Return "package" including instructions, thank-you card, data summary
- Instructions
- Partial Storyboard

All materials can be found in appendix I & J.

Procedure
Per patient and their caretaker, a session of roughly 60 minutes was conducted. It started by taking patients through discharge and recovery with a storyboard. They were asked about the struggles they had when recovering and how they felt during that time to prime them on the mental and physical burden as opposed to being healthy.

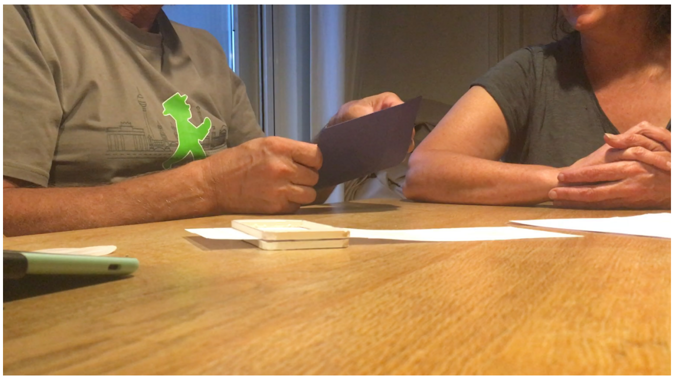


Figure 24: Test setting at the kitchen table

Provided afterwards are instructions for the patient and their caretaker to go through. They went through the recovery period timeline with the messages and finish with the package. At each touchpoint (messages and package) they answered a few questions. After they've gone through this "exercise" the session concluded with an interview.

Capturing insights
During the session all was observed
Video recording of actions + answers to questions

Follow-up questions

send-back
What aspect is triggering you the most to send-back?
What would hold you back in taking it to the mailbox?
What would prevent you from sending it back?
What are the positive aspects of this solution
What are potential issues?
What stimulates you most to send it back?
When would sending it back be the easiest for you?

Data overview
What do you like about the overview?
What does the data tell you?
What information do you think would help you to recover more quickly?
What information do you think woul help you to recover better?

Relationship
What did you value most in the relation with your caretaker?
What aspect of being taken care of would you be thankful for the most?
How do/did you value him/her taking care of you?

5.2.2 Test results and discussion

The outcomes and insights of the qualitative study is discussed per element of the concept. First the messaging is discussed, then the package and its elements. Following this the four main insights will be elaborated to conclude.

Messaging
The messages provided to the participants were received as mostly positive. The first message for example was by some seen as meaningless, only to be valued after receiving more messages. It was perceived as logical that a superficial message as first contact would precede other messages. Others valued the message enormously and immediately felt thought of. The first message sent towards patients therefore is the starting point of both the communication and perceived involvement.

Participants all appreciated the messaging as a channel. They also indicated that they would share such a message with their partner. Sending a text message to the patient is therefore also potentially a way of involving the other half of the "carepair" more.

The second message was perceived as more informative and reminded the participants of "something a doctor would say". The main reason for this was the vagueness of "if the pain allows it" which some literally had heard from their doctor.

It was indicated that more of this kind of information would already be helpful in order for them to determine whether certain pain would be normal or what kind of activity should be possible for them. The expectation was that such advice would come from conclusions doctors made based on the monitoring happening at the hospital. The feeling of being monitored created the expectation of receiving insights and for some even the desire to obtain all data.

The third message was perceived as very clear. Participants liked such clarity as it they now knew what to expect from the service in the following days.

Package
The different elements of the package evoked different responses. The instructions were perceived as clear and logical. Most participants indicated the map showing the nearest mail box was not necessary as they all knew where it was already.
A negative remark on the instructions was that the paper used during the session was thin and did not feel comfortable to place the band-aid on.
The assumption of being rewarding was invalidated. The data overview was not perceived as the rewarding element of the concept. Some participants enjoyed the overview but would like to see more of the data. Others were only interested in the meaning of the data for their recovery process.

Main insights
Sending back the device after having worn it for two weeks was perceived as a small effort by participants. To increase the motivation and ability of the carepairs for sending back the healthdot the study showed several factors that work, or provide an opportunity to improve.

- The hospital showing involvement is considered the most stimulating to actually send-back the device. It creates a feeling of reciprocation. This involvement was perceived by participants through contacting them regularly throughout the recovery period. The messages serve as a social factor increasing the motivation to send back the healthdot. Even though participants experienced the involvement as most stimulating to actually send it back, they expected some effort being made to enable easy send-back if someone wants the device back.

- Sending back the device is made easiest as possible by providing the material, but letting them choose when and where to take it to a mailbox. They want the control over this. They indicated an SMS reminder is perceived as helpful when they don't send it within two weeks after removal. The most basic requirement to increase the ability for patients is by providing all materials needed to send the device back. Participants expected these to be provided. Together with clear instructions providing these materials works as a facilitating trigger to decrease multiple aspects of the ability precondition. It decreases time, money, physical and mental effort.

- The patients expect to receive information on their progress which they feel like the hospital could provide by monitoring them. This information should translate the data into knowledge on their recovery progress. The data provided in the study did not have the desired effect on increasing the motivation to send back the healthdot. It did provide a key insight on how to improve patient experience while wearing the healthdot.

- The healthdot physically moving out of the house provides closure. Participants indicated that getting rid of the healthdot by sending it out of their homes meant the closure of a recovery phase. This was not taken into consideration before the study and is an opportunity for this project to emphasize on and furhter improve patient experience while increasing the carepair's motivation to send back.

5.3 Final iteration

5.3.1 Second creative session

The insights from chapter 5.2 allowed for an improvement of the concept. Another iteration would lead to a concept focusing more explicitly on the aspects that effectively increase the motivation and ability of the carepairs. The first step in this iteration was a creative session held with two design students.

The session used the choice architecture of Nudging to frame questions to guide ideation (e.g. What errors can we expect users to have). All associations with the words; Healthdot, Revalidation and Sending back where written down and used to describe the worst possible scenarios for asking patients to send back the Healthdot. Elements of these scenarios were then clustered on the three preconditions of Fogg's behavior model (2009); motivation, ability and trigger. Finally, these exercises led to brainstorming on solutions for these elements (figure 25&26). The outcomes were then used to improve the concept used in chapter 5.2 and results in the final design solution for this thesis that will be presented in chapter 6. How specific features were improved based on insights gathered during design development is elaborated in 5.3.2.

5.3.2 Features based on insights

As participants in the qualitative study indicated that messaging was most stimulating to send back, this was extended in the final design. The extension of this aspect is done by enabling a continuous connection and dialogue between the hospital and patient, through a communication platform, rather than a fixed number of text messages.

Participants in the study expected meaningful insights regarding their recovery based on the data that is being monitored. The platform allows to display insights and live up to the expectations of patients to get some feedback on their monitoring.

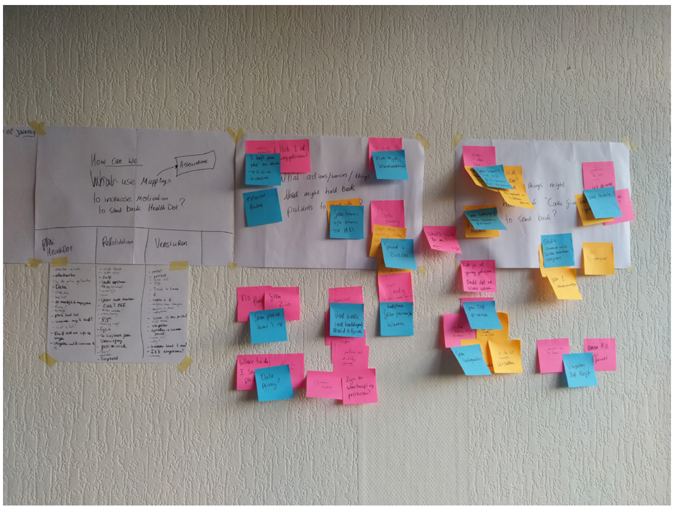


Figure 25 (Left) & 26 (Right): Clusters on the wall during creative session

Receiving several text messages was perceived as a logical build-up towards asking for the device back at the end of the recovery phase. The hospital being involved more in the recovery of patients while they are at home creates the feeling of reciprocation and increases willingness to send back the Healthdot. Sending back becomes a more logical part of their recovery. To be taken care of more while at home, patients wear the Healthdot, and afterwards they send it back.

To emphasize the logical build-up and increase it towards more of a ritual, patients receive an advent calendar to be placed at their homes. This also allows partners to be involved more since there is a physical thing in the house. Having them involved more could stimulate the social acceptance aspect of send-back behavior. Notifications can also be shared or accessed by other relatives or loved ones with access to the platform. Any loved ones visiting or staying over can become part of opening the calendar as well. The end of this calendar is also the end of the recovery phase. Physically sending the healthdot out of the house provides closure and the calendar build momentum towards this and emphasizes the ending of a phase.

Patients or their partners and loved ones want to be in control of when and where exactly they take the device to the mailbox. Therefore this remains the same as the earlier concept. They receive all materials necessary, to enable them to send-back the device with regular post. This will be provided in the calendar.

The materials provided to send-back the healthdot will be in the final box of the advent calendar. After opening earlier boxes of the calender, the final one emphasizes closure of a phase. Once they reached the final box, patients can gather the materials, remove the healthdot and send back the device through regular post. Through this, the sending back becomes part of their recovery and makes it feel much more logical to send it back than asking them at the end or only mentioning it at the beginning of their recovery period.

Final Concept

The final solution presented in this chapter integrates the insights from validation in chapter 5.2 and shows the elements leading to fulfilling the project's objective. The service concept is presented in 2 horizons, of which the short-term horizon is detailed for implementation within a year and the long-term horizon serves as a more visionary concept.

A service blueprint is used to describe how the concept works. This includes the entire use cycle of the Healthdot. Afterwards the business case is discussed and the specific costs are described together with the impact on the original scenario. Following is the environmental impact, which explains how the different horizons decrease the environmental impact. Finally, a description of the implementation steps needed will follow.

6 Final Concept

6.1 Horizons

The final solution to engage patients to send back the Healthdot, enabling a circular offer, is a communication platform in combination with an advent calendar. In this solution the Healthdot is redesigned to increase circularity. This solution is the long-term horizon situated in 2022.

The first step towards this solution that can be taken already towards this solution is horizon 1. This horizon includes a messaging service together with send-back materials provided to the patients and includes the Healthdot in its original design.

The conclusions of chapter 2.4 show the short-term and long-term opportunity for circularity. These serve as the basis for two horizons used in explaining the final concept. A timeline can be seen in figure 27.

As the focus in this project is on implementation, the first horizon is short-term towards the end of 2020. The first horizon evolves over time into horizon 2, aiming at 2022. Horizon 2 allows for improvement in hospital involvement, meaningful insights in their data for the patient and further emphasis on closure of the recovery phase.

Both horizons are explained using a service blueprint. Using this tool both concepts will be shown in detail on the physical and digital elements and how it all works. These blueprints are supported with textual explanation and additional visuals. Following is the business case, environmental impact and implementation. These three topics are discussed in that order but describe each horizon separately.

6.1.1 Long-term concept

In the long-term horizon a redesigned version of the Healthdot is discussed. This concept entails a communication platform, an advent calendar with send-back material so patients can send back the Healthdot to the factory where it can be refurbished. The service blueprint on the next page (figure 28) shows an overview of how the concept works.

Platform

Philips is already pursuing multiple initiatives regarding communication between care providers and patients. Examples are VitalHealth and Healthdossier which are communication platforms where a patient has an overview of all their care providers and can contact them. As these applications

Figure 27: Timeline showing both concepts

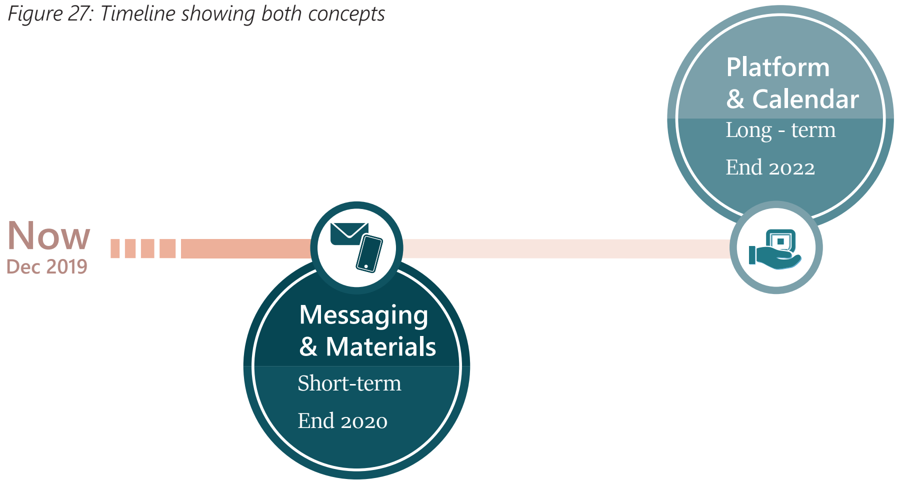
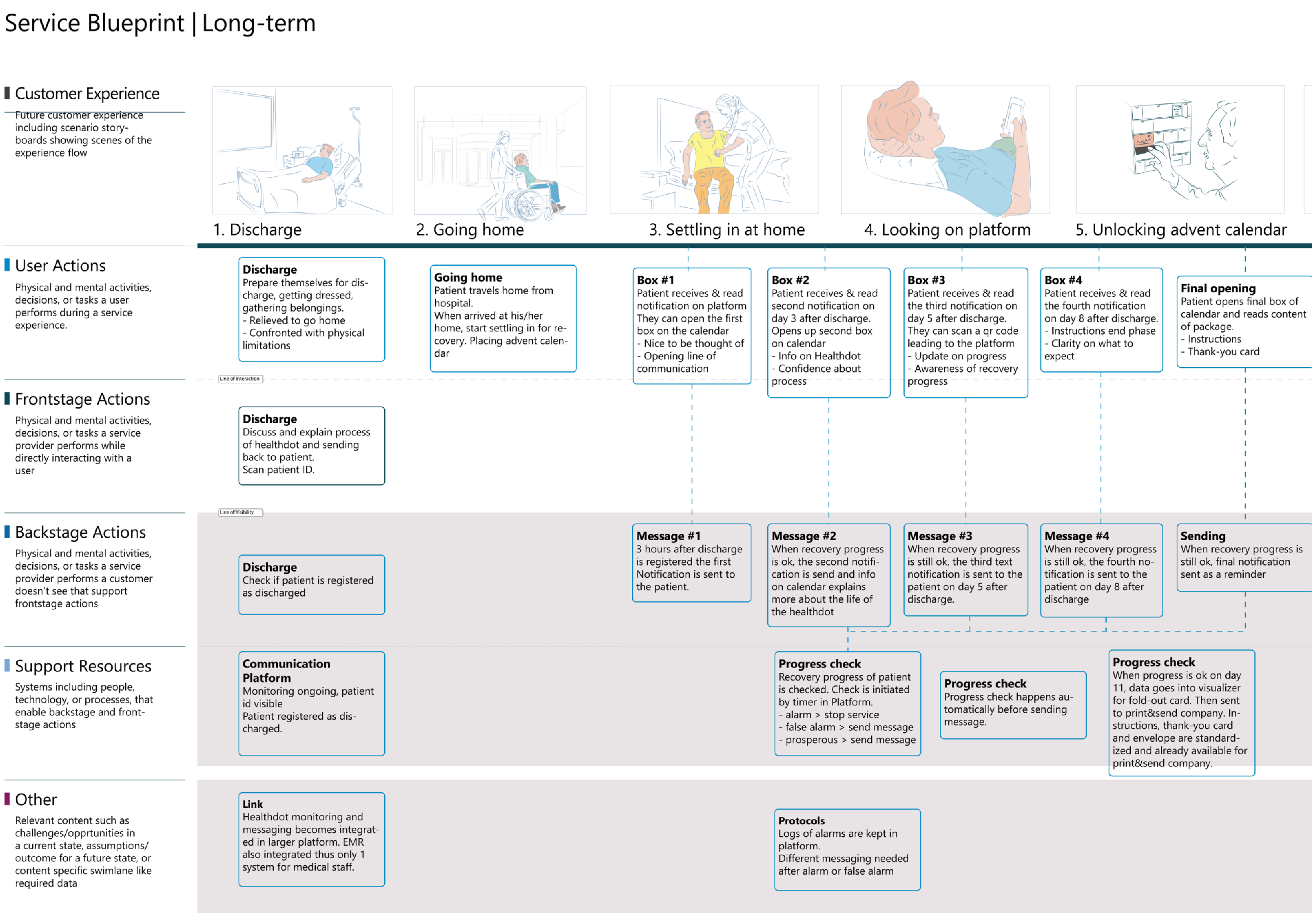
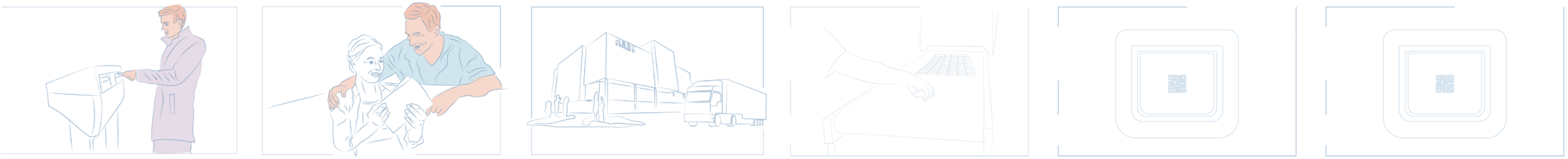


Figure 28: Service blueprint long-term horizon 2





6. Posting return envelope

7. Thanking partner

8. Factory operator

9. In production line

10. Cleaning

11. Refurbished device

Removal
Patient or partner removes Healthdot and places it on the instruction card. Then put the card inside of the return envelope.

Mail
Depending on physical ability of the patient, either the partner or patient him-/herself will mail the envelope.

Thank you
Patient uses the thank-you card to express appreciation for the care received by their partner or other loved ones.

Arrival at factory
Return envelope with worn healthdot arrives back at the factory

Reuse PCBA
Disassembly of device. Seperation of pcba, batteries, adhesive and plastic from housing.

Refurbishing
Removal of adhesive, casing to cleaning and quality check

Ready for shipment
Healthdot ready for shipment to hospital

Triage
Factory operator scans QR-code of device to see the use cycles and version

PCBA & Waste
Factory operator transfers PCBA to check-equipment. Seperates rest of components for correct disposal.

Adhesive
New adhesive is applied, device made ready for new shipment.

Post system
When return envelope enters the Post NL system, the factory receives a notification for device on the way

QR-code
Each device has a QR code. Old version of device goes to reuse PCBA. New version depending on amount of use cycles.

Production line
PCBA enters production line with new PCBA's. Assembly of components into complete device.

Cleaning
After cleaning casing device undergoes quality check. If okay it moves to next step in refurbishment

Mailbox
Return envelope can be posted like regular mail in a mailbox or drop-off point

Device tracking
Factory has a system tracking how many incoming devices to balance new manufacturing with refurbishment

Pre-production facility
Production line located at a Philips facility in the Netherlands.

Use Cycles
The PCBA can withstand 100-1000 use cycles.

Cleaning
Device can be cleaned with an alcohol based cleaning solution, disinfection only.

Figure 29: The platform has multiple functions

are already existing and partially in development and in use, it is easier for the Healthdot team to integrate communication functionalities into such a platform rather than developing one separately from these. Therefore, to enable more of a dialogue between patient and hospital which increases involvement from the hospital, on the long-term communication will happen on such a platform and patients are contacted by the hospital through the communication platform. The platform can be used on multiple devices including laptops and smartphones. Calling patients only happens when complications arise.

The communication platform provides a chat function in which the communication will mainly happen. The Healthdot team can use such a functionality to enable the hospital and patient to communicate and share data. Within the platform (figure 29) exist several other functions where patients can see who has access to their medical file, the prescriptions of drugs, treatment plans and appointments including the outcomes per care provider. It is not a platform that just hospitals can use, but also other care providers.

The platform enables more of a dialogue between patient and hospital and improves the patient experience overall. Next to that, such a platform allows to fulfill the patient expectations of meaningful insight in their recovery as the platform opens up a range of possibilities in viewing their data. Access can be given to a partner or other family and friends so they can also get insight in the recovery of their loved one.

Materials

The patient receives an advent calendar (figure 30) at the moment of discharge. Materials inside the calendar include instructions and a return envelope, so the Healthdot can be sent back through regular post. These materials will be described more detailed in chapter 6.1.2 with figure 33&34.

Patients receive the calendar in the hospital at the moment of discharge. It has several numbered openings to unlock during recovery. Patients are allowed to open one box a day in the right order. The calendar is linked with the previously discussed communication platform where additional explanation can be found on the working of the

- To be placed at home and keep ongoing engagement throughout recovery period
- Different boxes can be opened, with information on the Healthdot and recovery process
- QR codes linking to platform
- Send-back material provided in final box

Figure 30: The advent calendar has several boxes to open

Healthdot or insights can be gained in their personal, specific data that is being monitored. The patient is notified through the platform to open boxes of the calendar at several moments during recovery to engage the patients and build towards the send-back moment and closing of the first recovery period. The advent calendar allows for more engagement between the patient and his or her progress throughout the recovery period and more inclusion of the partner or other loved ones of the patient.

The calendar supports the carepair to experience a feeling of a ritual around the process of working towards full recovery. The final box marks the end of the recovery phase as it includes the send-back material and instructions to return the Healthdot. This last send-back action symbolises the final step towards full recovery, emphasizing the feeling of closure when the Healthdot package is physically moved out of the house and put in the mailbox.

Concept activation per patient

This concept focuses on surgeries for non-terminal patients as these were not involved in any testing or interviews.

A functionality in the monitoring dashboard, is continuously checking for any discrepancies outside of the threshold set for the values monitored by the Healthdot.

This functionality is connected to the communication platform. With this connection, it can be prevented to send any messages or show any information connected to the calendar that is not suited for the situation of the patient (e.g. when recovery is not going well). When a complication arises there are a large range of possibilities that could be the cause. Therefore it depends on the systems ability to aqcuire the nurse's notes on recovery progress if any changes in the information or messaging can be made.

Product design
To increase circularity and value retention from "parts-recovery" to "refurbishment" the Healthdot needs a redesign. The device can be redesigned to enable the refurbishment strategy in a way that the adhesive part gets replaced every use cycle. The batteries need to change into rechargeable ones. With this the Healthdot should be able to go through at least 5 use cycles, which is both a practical minimum next to being the amount after which the financial benefit is the most significant.

In chapter 2.3.2 the CE-ready requirements established within Philips for the medical consumables are explained. These serve as the basis and will be used to specify guidelines for the redesign of the Healthdot which are as follows:

1) Easy to clean, sterilize and restore aesthetic state.
As the Healthdot is a non-critical medical device (see chapter 2.1 or 3.2.2 for more on this) it can be cleaned with an alcohol detergent. The adhesive part needs to be easily removable and the casing needs to be cleanable as a whole without disassembly to make the cleaning easy.

2) Easy to assess and track performance (detecting material degradation & use cycles)
The original Healthdot has a QR-code which can be used for tracking use cycles. This QR-code has to be able to withstand at least 5 use cycles.

3) Easy to disassemble, repair and re-assemble
Next to the adhesive part being easily replaceable, the casing needs to be adapted for disassembly and reassembly in case a component needs replacement while other components still remain to work. This is to prevent destroying components when they are still valuable.

4) Modular design for forward and backward compatibility
Forward and backward compatibility means that the design is compatible with older versions as well as future versions. For the Healthdot this means that the redesign does not exlude all components of the original design next to being able to handle future improvements.

5) Standard, durable element selection
Elements of the device need to withstand multiple use cycles, hence need to be durable. The casing already withstand usage of a 14-day period but the material that it is made out of also needs to be durable. (i.e. no non-recyclable plastics)

Reverse logistics
The Healthdot going back to the manufacturer after each use cycle means that reverse logistics need to be in place. The following two elements are specified for this:

1) Fleet management, -or installed base management and 2) back-end operations, specifically the activities needed in the factory for value retention of the product.

1) Fleet management
Like specified with the CE-ready requirements, tracking use cycles and performance is needed in a circular offer. If an order is made for 1000 Healthdots, and it is certain that 500 used devices will return to the factory, it follows that 500 need to be newly manufactured. This example fits exactly. But how many devices would need to be newly manufactured

when it is unknown how many devices return to the factory? This is only a simple example, but becomes increasingly complex with multiple orders and many different sources of devices returning to the factory. For the Healthdot this entails balancing the order intake with manufacturing as well as keeping track of performance. This allows to also improve service to customers (which are the hospitals), in case of any malfunctioning. This tracking can be done in a separate system that factory operators can use to check and verify use cycles per device. The customer service department can use this to spot discrepancies with issues at hospitals.

2) Back-end operations

The redesigned version will likely launch when there are still Healthdots in the market with the original product design. This creates a challenge for the factory operations where then a distinction needs to be made between the versions. When the Healthdot arrives at the factory it goes through a triage. When the device has gone through less than 5 use cycles, the adhesive part is removed and the casing is cleaned. After attaching a new adhesive, the device is ready for another use cycle.

The redesigned version of the Healthdot has a smoother flow in the factory than would be possible with the original design. A device arrives at the factory in the return envelope. The factory operator takes the worn Healthdot out of the envelope and scans the QR-code with a dedicated phone. The phone then shows which version of the Healthdot it is, and how many use cycles it has gone through. The factory operator then places the device in the correct recovery process.

When this is still within the validated number of use cycles it continues. If not, it goes into the recovery flow of the parts recovery strategy, which will be elaborated in chapter 6.1.2.

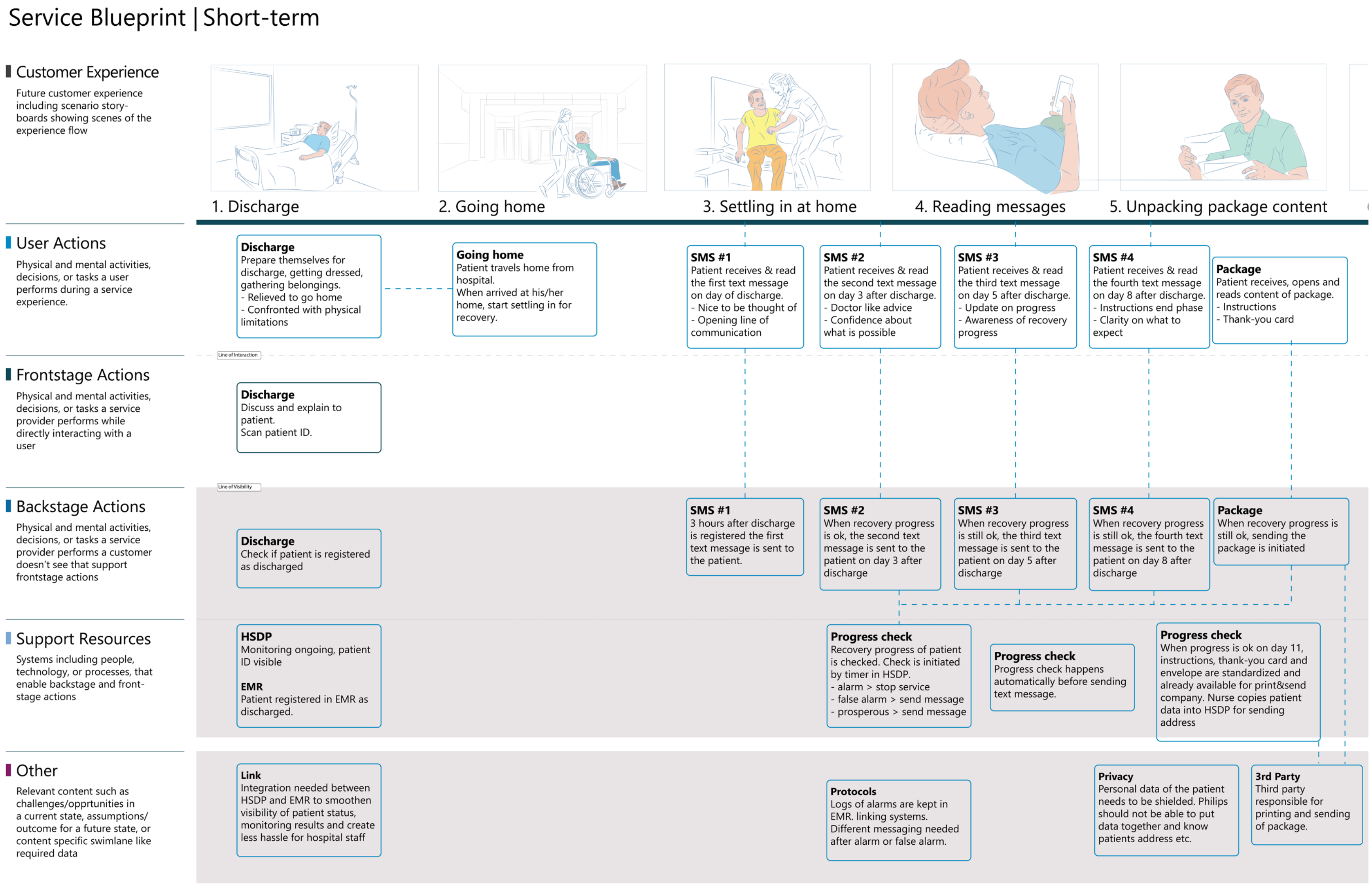
When it continues the recovery process for refurbishment the next step is removal of the adhesive. After this, the casing in its entirety can be cleaned with an alcohol substance or other disinfection agent. Like mentioned before, the Healthdot falls in the category non-critical on the Spaulding scale, meaning this would be sufficient cleaning. It is then quickly checked if working according to the set standard, followed by the placement of a new adhesive. It is then ready for shipment.

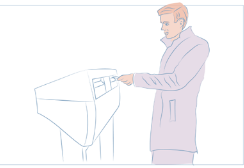
6.1.2 Short-term concept

In order to reach horizon 2 and realize the long-term concept, a first step needs to be taken. This step is a concept feasible for implementation on the short-term, namely the "short-term concept". In the short-term horizon, the original version of the Healthdot product design is used. This concept entails a messaging service and send-back materials that will be provided to patients. This gives the patients the feeling of involvement from the hospital and making it as easy as possible for them to send it back.

As the results of chapter 5.2 show, the hospital showing involvement towards the patient throughout the recovery period at home is a key aspect of motivating them to send-back the Healthdot. Since hospitals are trying to move the care they provide out of the hospital more, communicating with patients that are not physically at the hospital becomes increasingly important. Nowadays communication with patients during recovery only happens when a complication arises. This adds to the feeling of uncertainty that patients have while recovering at home.

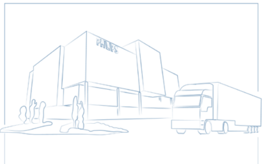
Figure 31: Service blueprint short-term horizon 1





6. Posting return envelope

7. Thanking partner



8. Arrival at factory

9. In production line

10. Assembled device

Removal
Patient or partner removes Healthdot and places it on the instruction card. Then put the card inside of the return envelope.

Mail
Depending on physical ability of the patient, either the partner or patient him-/herself will mail the envelope.

Thank you
Patient uses the thank-you card to express appreciation for the care received by their partner or other loved ones.

Arrival at factory
Return envelope with worn healthdot arrives back at the factory

Device version 1
Disassembly of device. Seperation of pcba, batteries, adhesive and plastic from housing.

New device
Reused PCBA assembled in new Healthdot.
Ready for shipment.

PCBA & Waste
Factory operator transfers PCBA to check equipment. Seperates rest of components for correct disposal.

Post system
When return envelope enters the Post NL system, the factory receives a notification for device on the way

Production line
PCBA enters production line with new PCBA's.
Assembly of components into complete device.

Mailbox
Return envelope can be posted like regular mail in a mailbox or drop-off point

Post system
Post NL alert service required to inform on "track&trace".

Pre-production facility
Production line located at a Philips facility in the Netherlands.

Use Cycles
The PCBA can withstand 100-1000 use cycles.

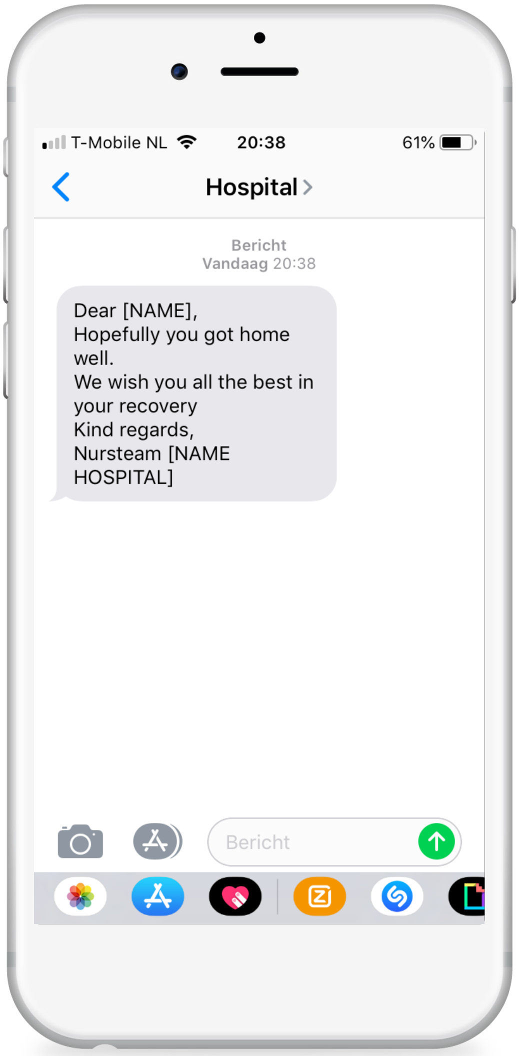


Figure 32: Patient receives text messages from the hospital

Messaging
In the short-term concept patients are contacted by the hospital through SMS (figure 32). This functionality is easy to implement within the current monitoring system. Calling the patient only happens when a complication arises.

The messages are sent automatically by a messaging service integrated in the monitoring software provided to the hospitals as part of the Healthdot offer. Multiple messaging platforms have ready-to-go APIs that can be implemented straight away in the monitoring software. Details on the implementation of this can be found in chapter 6.5. The name of the sender that is visible for the patient can be specified per hospital. That means the patient receives a text message with the name of hospital as sender.

Four messages are sent at specific times during the recovery period at home. The first message is on the day of discharge, and continues by default on day 3, 5 and 8. The timing of the messages is regulated by an automated timer function. If the system notices that the 14-day wearing period ends before a patient will have spent 8-days at home, the timing and content of the messages will automatically change accordingly. The first message aims to establish a connection. The second message provides a familiar doctor-like communication style. The third message gives some reassurance and the fourth message includes clear instructions to manage expectations.

Messages:
The text messages are made for Dutch patients but for the explanation in this thesis translated to English.

1. First message: establishing connection on day of discharge. This message is triggered on the day of discharge. When the patient's discharge is registered in the monitoring system, a 3 hour timer starts. After 3 hours the message is sent.
Dear [NAME],
Hopefully you got home well.
We wish you all the best in your recovery.
Best regards,
Nurseteam [NAME HOSPITAL]

2. Second message: Day three after discharge
Dear [NAME],
It is now day 3 of the recovery. After the kind of surgery that you underwent it is normal to experience some pain. You can carefully try to walk a bit if the pain allows it. If the pain is still heavily present you can reach us by phone.
Best regards,
Nurse team [NAME HOSPITAL]

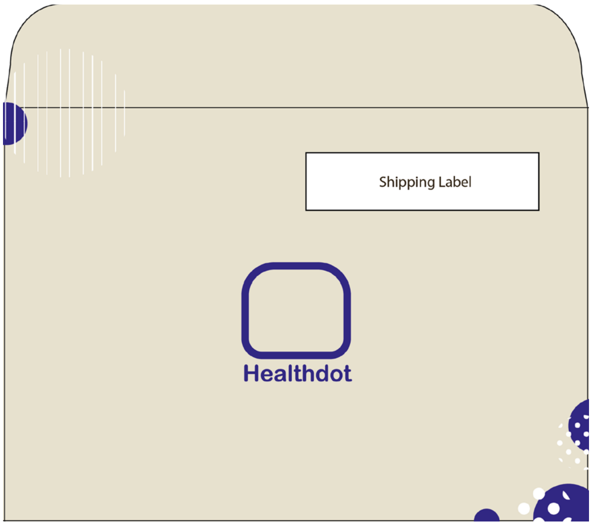
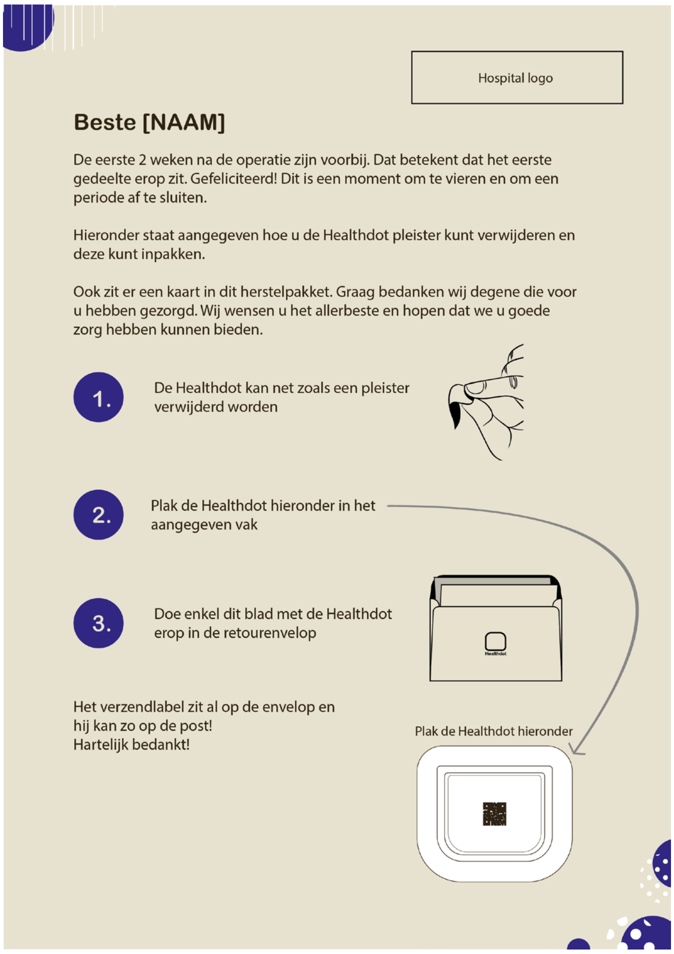


Figure 33(Left): Envelope provided to participants

Figure 34(Below): Instructions provided to participants



3. Third message: Day five after discharge
Dear [NAME],
It is now day 5 of the recovery.
We are still keeping track of the data from the Healthdot and it looks good.
Best regards,
Nurse team [NAME HOSPITAL]

4. Fourth and final message: Day eight after discharge
Dear [NAME],
The active period of the Healthdot is almost over. In 3 days it will stop working. You will receive a package through regular mail with further instructions on removal and send back.
Best regards,
Nurse team [HOSPITAL]

Materials

All materials necessary to send the Healthdot back to the factory are provided to the patient. This includes a return envelope and instructions for the removal and send-back of the Healthdot. These are provided towards the end of the 14-day period to prevent patients from losing it during this period, which would result in an increased difficulty of sending back.

It can be send-back through regular post. This allows them to have control over when and where they will put it in the mailbox. It also fulfills one of the key requirements of patients expecting the return of the Healthdot to be free of charge and easy.

Next to that, regular post means staying away from extra environmental impact by having a dedicated pick-up service. It also allows the patient to send it back in a familiar way, which is helpful in decreasing the mental effort needed.

Materials will be sent through an automated trigger in the monitoring dashboard. The dashboard already registers the progress of recovery in terms of time and the trigger can be set on day 10, for example. Depending on the mail delivery it will then arrive on day 12 or day 13. Delivery happens within 24 hours, except on Sundays (in NL). Delivery on day 13-14, would mean the package needs to be ready on day 11 or 12. If day 14 appears to be a Sunday, the package should be ready on day 11.

Content

The send-back material consists out of multiple parts:
1) The return envelope including shipping label (figure 33) (large size in appendix K)

2) Instructions for removal of the device and for sending-back the Healthdot (figure 34)(large size in appendix K)

3) A thank-you card for their partner or other loved ones that took care of them.

To make sure that the provided materials don't cause an increase in environmental impact all content of the package is made out of biodegradable paper. As this has a bit of a yellowish fiber color, the figures show a non-white background.

The return envelope is a C5 envelope size which corresponds to A5 paper size. It complies with the requirements for envelopes set by the postal service in the Netherlands. (PostNL, 2019a)
The instructions will be A4 size, folded double so it fits in the envelope. The instructions entail a short introduction followed by a step-by-step explanation on removal of the Healthdot and placing it in the return envelope.

The thank-you card in the package allows the patient themselves to either write something personal on it and give it to their partner or send it to someone who helped them out during recovery.

Concept activation per patient
This concept focuses on surgeries for non-terminal patients as these were not involved in any testing or interviews.

To make sure a message is not sent to a patient that experiences complication there is a progress check. A built-in functionality in the monitoring dashboard exists to check if a message should be sent and if the final package should be sent.

If the software notices a discrepancy in the values monitored by the Healthdot, a notification alerts the nurse on duty. This nurse then calls the patient according to a protocol in place. According to this protocol they have a questionnaire for the patient which they use to check for possible complications. According to the Healthdot team, most of these cases are false alarms. A department with 1000 patients, receives on average 3 notifications per day with 2 or 3 of them being false alarms.

These alerts and calls are all noted in the EMR with the corresponding outcome. The monitoring dashboard checks before sending each message if this happened and if it was a false alarm or not. Based on the check the message is sent or not.

Reverse Logistics
The current version of the Healthdot, needs to be disassembled before the PCBA can be reused. After arrival in the return envelope, the casing including adhesive is removed. This removal requires additional equipment. The mechanical design engineer of the Healthdot team confirmed that a small 3d mill is suitable and can be used for this disassembly process. The adhesive is categorized as bio-waste and therefore needs to be disposed of correctly. The casing material can be collected and afterwards the batteries and PCBA can be taken out. The batteries also need to be correctly disposed of. These then go to a recycling center for batteries where the materials will be recycled. The PCBA will be transferred by the factory operator to the electronics testing equipment. When this check goes well, the operator transfers it to the production line with new PCBAs. The PCBA is then placed in a new casing, and the Healthdot is ready for a new cycle.

6.2 Business Case

Setting up recovery activities that currently don't exist or don't happen requires budget. As financial considerations are a key factor of the decision making in going circular, showing the impact of going circular financially is crucial to create wide support within Philips.

This chapter describes the financial impact of both horizons. The costs of the short-term concept are more detailed and validated, while some rougher estimations are made for the long-term concept. Both improve overall profitability significantly and save costs by reusing components. Reuse of components and simplifying manufacturing processes are the main reasons the profitability increases and explains why for the Healthdot going circular, means saving money.

6.2.1 Costs

The specific costs for the horizons are based on manufacturing prices of the original bill of materials and available pricing from postal services. The costs of the back-end operations are validated with the project manager of the Healthdot team, who has experience with setting up the refurbishment line of another Philips product. The full overview of the cost price calculations in the business case can be found in confidential appendix B.

Horizon 1: Short-term

The business case of the original offer is based on a transactional product sale without reusing any part of the device. Hence, any additional costs or savings, inevitably have an impact on the financials. The difference in profit is calculated over a period of 5 years. Note that this calculation is based on a transactional product sale and not a service model.

The short-term concept with the current version of the Healthdot design would result in a 30% decrease in costs. It is a cheap service to implement and increasing overall profitability by 10%.

Specific costs of takeback-system

The takeback-system as a whole will cost €7 per device that will go once through a full use cycle. If devices don't get sent back but the "patient service" is activated, €2 is spend per device. For each aspect of the takeback-system, the following paragraphs explain and describe how the costs are specified and how they are taken into account for the business case.

Materials, postal fee and messaging

Sending all materials to patients costs €0,58 per sending with 2500 units per year. This is based on the category "small mail", with only paper content sent by PostNL within 24 hours (PostNL, 2019b).
The price per returning package depends on weight. The Healthdot itself is only 12 grams resulting the format to fall in the most basic and light-weight category of post meaning that for 2500 units a year the price per unit would be €0,86 euros. (PostNL, 2019c)

The costs of sending automated text messages varies per country. Since the first country targeted is the Netherlands, the price rate for this country is used. This comes to €0,07 per message. (Messagebird, 2019)

At the factory

For the activities that need to happen at the factory the costs are specified for disassembly and reuse of PCBA. These activities lead to a need for additional equipment next to cleaning and waste disposal.
Extra equipment needed for disassembly is calculated per device instead of a single investment. Equipment

	Original scenario (No circularity)	Short-term scenario (Parts Recovery)	Long-term scenario (Refurbish)
Use cycles per year	100.000	100.000	100.000
Price per use cycle	100%	70%	48%
Overal profits	100%	110%	117%

Figure 35: Comparing scenarios shows going circular means saving money

needed for disassembly is comparable with that what's needed for assembly. This makes the cost for this per device to be €2,50.

Similar to the equipment, the operator time is equivalent with the time needed during assembly. As the operator only spends time on devices that return, this is also calculated per device. The operator time will be around 2 minutes, which then accounts for €2,50 per device.

According to the mechanical design engineer from the Healthdot venture team, cleaning or decontaminating the used devices when they arrive at the factory is done during disassembly. This therefore becomes part of the equipment costs.

The batteries, adhesive part and plastic from the casing will need to be disposed of correctly. These all differ in costs. Disposal cost are dependent on specific types of waste, and go per weight. The cost for the waste produced by 100.000 devices is estimated to be €0,15 euros per device.

Horizon 2: Long-term
For the long-term concept the Healthdot is redesigned to increase circularity. Compared with the original offer this results in a 53% decrease in costs while overall profitability increases further to 17%.

While the costs for the short-term horizon are mostly validated, the costs for this scenario become more rough estimates and an indication of potential. Nonetheless it still provides an insight into possible impacts on the business case.

Platform & Calendar
The costs for integrating functionalities in the communication platform is unknown. This however depends on internal budgets within Philips and needs further research internally.

At the factory
The back-end operations required for this concept consist out of a triage, cleaning and quality check.This means less complex equipment and less operator time is needed compared to horizon 1.
For horizon 2, the cleaning phase becomes more prominent as the back-end operations only entail cleaning and quality checks. Based on other devices that also only need similar cleaning the cleaning is estimated to be 1 euro per device.

The needed operator time decreases as now also the assembly of new devices becomes less. More devices only require new adhesives. Time needed is estimated to cost €1,50 per device.
As the Healthdot is redesigned and now only the adhesive is disposed of, the amount of waste decreases. The rates for waste disposal then become negligible.

6.2.2 Comparison
When comparing these scenarios to the original scenario with no circularity it becomes clear that going circular results in saving money. A practical threshold of 5 use cycles is set for the long-term concept to minimally be able to go through (as described in 6.1.1). This was discussed with one of the company supervisors as a logical threshold.
To compare the scenarios the amount of use cycles is assumed to be 100.000 per year. Figure 35 above shows how the cost price per use cycle and overall profitability differs with the original scenario. The original scenario is used as the baseline of 100%.
A graph plotting the profit can be found in confidential appendix F.

6.3 Environmental Impact

In chapter 3.3.2 is discussed how the LCA of another patch made by Philips is used to estimate the environmental impact of the healthdot. In this part of the thesis however, the environmental impact is discussed on a more detailed level, including the service concepts and different versions of the product design. This is done per horizon. The amount of decrease in environmental impact is discussed with a business analyst in Philips who performed the LCA of the SUV patch to validate the assumptions made regarding actual impact.

6.3.1 Horizon 1: Short-term

Based on the LCA of the similar Philips patch the Recipro score is 133 mPt and carbon footprint is 1,18 kgCO2eq. This is comparable to driving approximately 4 km in a car.

*ReCiPe method ecoscore: Thousand ecopoints is equal to the environmental impact of a single European citizen in one year.

The results of this LCA (Confidential Appendix A) show that the biggest impact arises from raw material and component production. The second biggest impact comes from assembly. Packaging, transport and disposal of the product are considered to be negligible.

As mentioned in 2.3.2 this LCA shows that reusing the PCBA reduces environmental impacts with 35%. Due to the recovery activities needed for reuse this is decrease in impacts is corrected to 30%.

The materials provided within the service concept are made out of fully recyclable paper and ink which has a negligible impact on the overall environmental impact. Using the regular post system is another aspect reducing extra impacts. The messaging service is such a simple function that server use is also negligible.

6.3.2 Horizon 2: Long-term

As discussed in chapter 3.2.2, moving up the scale of circularity would mean less waste and higher value retention. The activities needed for redesign also have an impact on the environment, however. In determining the circular strategy Lieder et al. (2017) suggest that this "design effort" needs to be assessed for multiple strategies as well. Due to Philips' goals of zero waste to landfill and the takeback of all medical equipment the impact of this design effort is not taken into account as increasing circularity is beneficial for waste reduction.

Decreasing the environmental impact further than 30% depends on several aspects. Product redesign goes according the CE-ready guidelines described in chapter 6.1.1. This allows for smoother recovery operations at the factory. Only cleaning is needed, and both the batteries and casing are reused.

Such a redesign would mean the manufacturing process in place for completely new devices is used less. The LCA of the patch discussed earlier, provides the means to make an educated guess on an extra reduction of environmental impact.
Redesigning in order for the casing, batteries and pcba to be cleaned, completed with only a new adhesive and still the same patient service would then approximately lead to a 50% reduction in environmental impact compared to the original non-circular scenario.

6.4 Implementation

Horizon 1 is the first step towards the final solution in horizon 2. The short-term concept made in this thesis, can be implemented by the Healthdot venture team within approximately a year. The specifics of what can be implemented in this first year and what would follow later is specified in this part of the thesis and described per horizon.

The venture team aims to launch in 2020. That gives the team roughly a year from the moment of writing this thesis and launching the first batch of devices. The long-term concept is for 2022 and thus has an additional two years to be implemented.

6.4.1 Horizon 1: Short-term

For the short-term concept different aspects need to be set-up. Part of this are the recovery activities at the factory and another part is the realization of the messaging and send-back material.

Disassembly equipment

In 6.1.2 can be found how the Healthdot can be disassembled. In order for this to work additional equipment is needed in the production line. In the Healthdot venture team the mechanical design engineer noted the feasibility of this with a small 3d mill. He just expressed to need some time and resources to figure out the exact detailed flow of disassembly.

This flow of disassembly contains all specific steps after the device has entered the factory and is taken out of the envelope. It is still unclear if a set-up that would crush the adhesive and casing, leaving the batteries and pcba to be taken out, is more favorable over a set-up that would carefully cut open the casing leaving all components to be separated. The first set-up would be easiest in containing the contamination, while the second one would be easier in separating components and correct waste disposal.

One employee is needed to determine the actual set-up for this in the production line. For this it is necessary to collaborate with the factory to determine space and resources needed.

Messaging function

The messaging function shown in the service concept, is easy to implement due to its simplicity. There are however many different providers of different messaging APIs that can be implemented in software. They all have similar pricing ranges to use and are scalable worldwide as well. Therefore, it depends on the system architect's preference for type of coding in the api that would enable the decision.

If for whatever reason the API is not readily implemented for launch, the messaging services can also be used independently. This is however more labor intensive as it requires more manual handlings. This is a last resort to use messaging during actual launch. It can be used however for further testing by the healthdot venture team.

Fleet manager role

For proactively managing the installed base of devices, successful reuse of the Healthdots is crucial. Setting up a dedicated role in the team to ensure this, similar to what happened with the a Philips project in the US, is therefore needed. The installed base manager from that project was consulted to verify the need for this. Based on their experience, 1 Full-time employee is needed. An extra employee requires extra resources, and needs to be allocated to an internal budget.

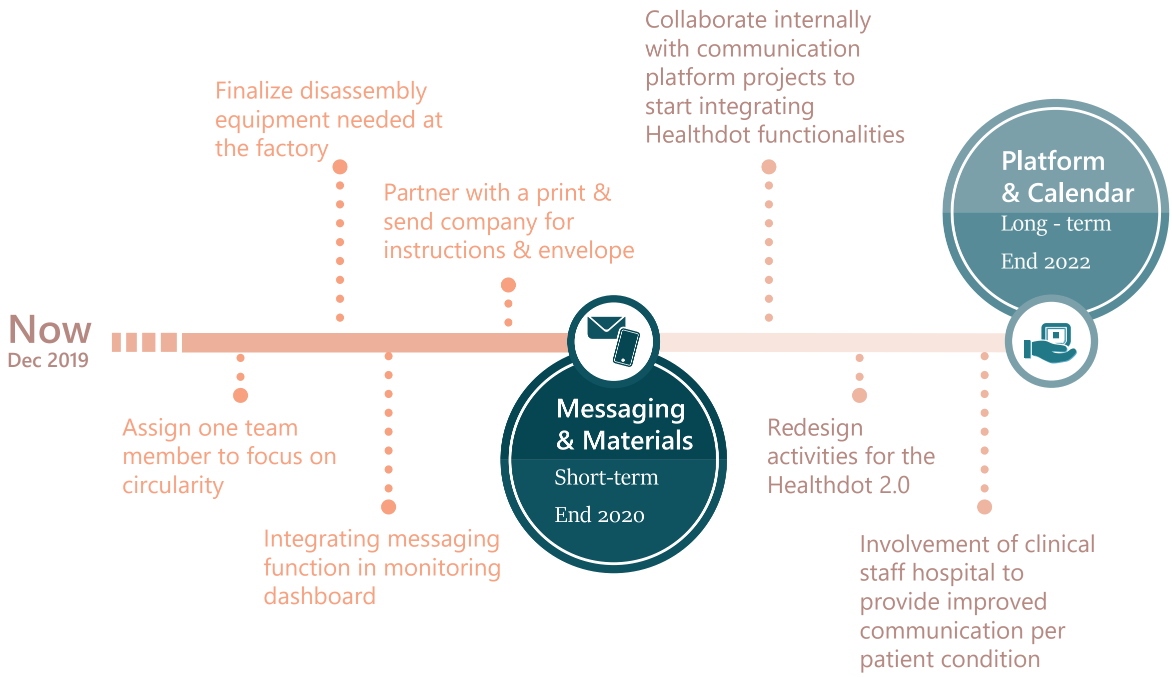


Figure 36: Several implementation steps over time

Since the launch of the Healthdot in 2020 doesn't entail a large pool of clients and large amount of devices the role would ultimately start as someone responsible for implementing circularity. This role would then gradually transform into the dedicated fleet manager function, who will be responsible to keep the devices circular.

Package

The package including its materials is already specified in the service concept. That leaves the following items to be done to implement it in the workflow. Philips needs to come to an agreement with the hospital for the use of hospital logo's in terms of branding. The Healthdot team needs to search for 3rd party to print and send everything. Starting in the short-term concept, the Healthdot team needs to look into possible PostNL collaboration with the installed base manager.

6.4.2 Horizon 2: Long-term

The implementation steps for horizon 2 are discussed on three main aspects. First the redesign of the device itself is elaborated, and the development of the advent calendar. Secondly, the integration of Healthdot functionalities into communication platforms is described. Finally, the clinical aspect of the communication is addressed.

Product design

Moving up the scale of circularity towards reuse means a redesign of the product. Rechargeable batteries are needed to smoothen the back-end operations and to not replace them every use cycle. This requires a change in design as there need to be charging connectors. This means a change in the casing and in the internal electronics.

Casing

The casing needs to withstand cleaning and multiple use cycles. Next to that, it needs to be easier to disassemble at the EoL for smoother recovery of materials.

This forms a challenge for the product design team that needs to follow certain guidelines made by Philips' group sustainability:

- Products are certified for a fixed number of use cycles.
- Tracking technologies such as barcodes or other marking needs to be able to withstand disinfection as well.
- Product is resistant to disinfection agents and will not degrade external cover and expose inner electrical elements.

Integration into vitalhealth/healthdossier

The service concept shows messaging towards the patient. With multiple initiatives going on in Philips, the Healthdot functionalities need to be integrated into these platforms. These are huge projects, but the integration is key to prevent further scattering of efforts. Currently known are two main initiatives on communication platforms between medical institutions, hospital staff and patients. These are Vitalhealth and Healthdossier. Starting to collaborate with these initiatives would create enough preparation so that when such a platform is launched, the circularity of the Healthdot benefits.

Communication treatment specific

Remotely providing clinical advice is extremely difficult, without having a medical professional examining the patients' situation. Communication towards patients that has meaning for them on their specific recovery progress needs to be carefully examined. Different projects within Philips that are part of the platforms have a similar struggle. Many clinical treatments vary depending on all secondary conditions patients have. The Healthdot team needs to actively collaborate with teams within Philips to ensure meaningful communication does not impact patients negatively.

Evaluation

Within this final chapter the design is evaluated on four aspects; Desirability, Feasibility, Viability and Integrity. The results of this project are discussed to interpret the insights in relation to Philips and design for behavior change.

The limitations of the project are explained and finally the report finishes with a conclusion on how the objective is reached and an answer to the research question is given.

7 Evaluation

7.1 Four aspects

In this part of the thesis the design will be evaluated on Desirability from both the patient and Philips perspective, Feasibility in terms of technology and implementation, Viability in terms of cost saving and business case and Integrity in terms of environmental impact.

7.1.1 Desirability

Patient

Currently, a patient that is recovering from surgery has a terrible experience. Not only do they go through the physical and mental burdens of being sick at home but also experience confusing information and insecurity. The validation in chapter 5.2 shows how part of the short-term concept improves the patient experience through contacting the patients while they are recovering at home.

The final design in this thesis entails a possibiltity for improving the patient experience significantly compared to the current status. Horizon 1 is validated to improve the patient experience and participants indicated they would have liked such involvement shown by the hospital.

Philips

According to a one of the business partners at Philips Design, there is even an emerging request from hospitals towards Philips to help them in a transition towards a sustainable business. This makes the design proposed in the thesis a promising opportunity as it allows for decreasing hospital waste while simultaneously simplifying the workflow of medical staff. Next to that, the design shows a way for Philips to further improve the lives of people by improving the healthcare a hospital can provide.

7.1.2 Feasibility

According to one of the company supervisors involved in the Healthdot team, Horizon 1 is extremely feasible. On the longer-term the product design seems feasible but requires more thorough research by the engineers of the Healthdot team for exact component details. The redesign requirements such as rechargeable batteries and casing design in this project are received as options but are actively investigated for the second version of the Healthdot. Since their activities currently still focus on preparing the release of the Healthdot onto the market, the guidelines need further refinement which requires more collaboration between the hospital, the Healthdot team and Group Sustainability.

7.1.3 Viability

Going circular results in saving money in the case of the Healthdot. Reusing the PCBA in horizon 1 means reuse of the most expensive component of the device. The low costs for the messaging service and send back materials needed for value retention are almost half of the costs for a new PCBA. With respect to testing the response rate of patients actually sending back the device, further testing is needed. This project focused on exploring the opportunities and did not include a quantitative study.

On the longer-term, further optimization of the factory operations is enabled by horizon 2. Increasingly larger amounts of money can be saved by going circular. Because of this, the business case shows profitability rising with more than 10%. Out of scope for this project was to discover which exact business models suitable for the Healthdot case. To ensure a sustainable business case in the future an exploration into the opportunities is required. Within Philips there are multiple initiatives ongoing related to circular business models. These can be explored to find out what a relevant circular revenue stream for the Healthdot might be. Pay-per-use for example is an option close to the original transactional sales offer which might be easy implementable. Caas (Consumables as a Service) is a proposition in development at Philips, which focusses on subscription models for multiple types of consumables per hospital. Their struggles in getting hospitals on-board with subscription models shows the difficulty, indicating more extensive research needed on this aspect.

7.1.4 Integrity

Compared to the original scenario, the design proposed in this project decreases the environmental impact significantly. Reusing the PCBA causes the biggest decrease in impact while further reduction mostly lies in a less intensive manufacturing process. The use of existing logistics infrastructure from postal services and all materials provided to patients made out of biodegradable materials also does not add additional pollution. Due to Philips' own objectives and possible regulations that might tighten, it is critical that circularity increases further over time.

7.2 Contribution

Philips

As a business undergoing a transformation to become circular, this project adds to the practical implementation of the circular categories, specifically those adapted for the medical consumables. Next to that, it contributes to reaching several objectives that Philips has set for itself:

- Retrieving all medical devices
- Medical consumables contributing to circular revenue by 2025

The final design allows Philips to add yet another proof point of their transformation towards circularity. The thesis was an exploration of how a product in the challenging category of medical consumables could become circular and showed that Philips can benefit financially, while decreasing environmental impact and improving their distinctive value proposition in the market.

Knowledge

Design for behavior change in a CE is still an overlooked topic where many studies are theoretical and focus on product design. This thesis focused on consumers and showed how they are crucial in retrieval of devices enabling circular models.

The behavior models used in this project prove to be useful for other designers who are aiming to have their users perform particular behaviors in a practical manner without forcing them. As they are useful in both analyzing the status quo and to design specific elements, they can be used throughout the design process.

7.3 Limitations

Within this thesis 2 horizons are proposed to motivate and enable patients to send back the healthdot after wearing it at home, enabling a circular offer. The following limiting factors need to be considered.

Project scope

To increase the short-term feasibility and affect the offer for the launch of the first batch the focus of the project was on implementation, therefore designing within the existing business model of the Healthdot. This limited the project in pushing for the biggest circular impact as that may have required a total redesign of the entire business model as well. Next to this, the scope included the product itself but was not focused on in-depth product design which limited options regarding other ways of patient monitoring.

Literature study

During this project, literature on both circular economy and behavior change was reviewed. Due to the large amount of literature on these topics some more theoretical aspects might be missing. This also related to the practical focus of this project which prevented the project from going in-depth on theoretical models in literature. Due to the specific and highly regulated medical industry however the literature on circular economy serves as a proper general background.

Access to target group

A big practical limitation for researching the users in this project is the availability of patients right after surgery. Not only access to them but also their physical and mental well being raises ethical considerations to test with them. For this reason, the participants in interviews and the qualitative study are people who have had surgery in the past and are now healthy again. Additionally, the participants in interviews and qualitative study all recovered from their surgery and were not fighting for their lives. The perspective of patients with a terminal condition is not gathered and might differ. Different aspects might work to increase their motivation or ability.

Similar to limited access to patients, hospital staff has also limited availability. Especially with the complexity in this project of having multiple stakeholders that interact with the product not all perspectives could be validated. Especially the many different departments within hospitals that are involved created a hurdle to run a full trial use cycle for example.

During the design phase the product design is only adressed to a certain extent. Due to the complexity in clinical treatments and the difficulty in getting the usability right for such a device this was deliberately done. Next to that emerging technological trends related to patient monitoring are not taken into account.

7.4 Conclusions

The core aim of this thesis was to investigate how the healthdot offer can become circular with the original offer as starting point. More specifically, the project focused on reaching the following objective:

“Engaging patients to send back the Healthdot after wearing it at home in order to enable a circular offer.”

After analyzing the ecosystem of the healthdot it became clear that the most promising opportunity lied in retrieval of the device through send-back by the patient. This however, poses quite a challenge as they are both physically and mentally burdened during the period in which they would need to act.
The main research question was: How to enable and motivate patients recovering from surgery to engage in circular decision making and send back the device? The final design answers this question next to showing the financial potential of making the Healthdot circular.

From the qualitative study it can be concluded that patients recovering from surgery can be motivated to send back the Healthdot to Philips in two ways. The hospital showing more involvement towards the patients by taking care of them while at home, is the most motivating for patients. Increasing their motivation in their social environment can be done through inclusion of their loved ones that are involved.

Enabling patients to send back the Healthdot can be done by decreasing the physical and mental effort through providing all materials necessary. Additionally, clear instructions on how to remove and send-back the device need to be given as well.

The circular offer enabled by patients sending back the device with the current version of the product in the category “parts recovery” and can be improved with a redesign on the longer-term to a refurbishment strategy.

This thesis led to the Healthdot venture team prioritizing a circular offer for the launch of the first batch instead of a future possibility. They are already actively investigating the possibilties for the product redesign related to horizon 2. Even though this design is the first step towards circularity for the Healthdot, it allows Philips have yet another proof point for sustainable acting. Next to that the design allows them to improve their offer towards hospitals by enabling them to create a better patient experience during recovery at home and last but not least, decrease the impact on the environment.

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